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ANNUAL U.S. ARMY HUMAN FACTORS ENGINEERING CONFERENCE (5TH), 22--ETC(U)

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Fifth Annual

ARMY HUMAN FACTORS ENGINEERING CONFERENCE

21-24 SEPT. 1959

REDSTONE ARSENAL
HUNTSVILLE, ALABAMA

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ARMY RESEARCH OFFICE
WASHINGTON 25, D. C.

CRD/J

26 January 1960

SUBJECT: Fifth Annual U. S. Army Human Factors Engineering Conference: Foreword and Transmittal

TO: See Distribution

1. This Report is the record of subject Conference held at Redstone Arsenal, Alabama, 21-24 September 1959, and is published and hereby transmitted for the information and retention of the personnel and agencies indicated on the distribution list. The Conference was attended by the persons listed in Appendix 1 of this Report, and is annually sponsored by the Army Research Office of the Office of the Chief of Research and Development, Department of the Army.

2. The continued annual sponsorship of these Conferences by the Army Research Office is a reaffirmation of the value they have demonstrated in facilitating interchange of information among the Technical Services and USCONARC on human factors engineering problems and accomplishments. In addition, the Appendices to this Report continue to constitute the sole current authoritative compendium of the human factors engineering work programs of the Army Technical Services.

3. The five years of these Annual Conferences have now brought into full mutual awareness and coordination the diverse separate elements of Army human factors engineering activities. As indicated in General Trudeau's keynote address to this Conference, it is now appropriate to consider enlarging the scope of future Conferences to include not only other elements of the Army's Human Factors R&D program, but related activities of civilian industry.

4. It is anticipated that the Army Human Factors Engineering Committee will give careful consideration to developing the best means thus to enlarge the scope of future Annual Conferences.

FOR THE CHIEF OF RESEARCH AND DEVELOPMENT:

Wm. J. Ely

Wm. J. ELY
Brigadier General, GS
Director of Army Research

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(6) **Conference Report**

FIFTH ANNUAL U.S. ARMY HUMAN FACTORS ENGINEERING CONFERENCE (5th),

22, 23, 24 September 1959

REDSTONE ARSENAL, ~~ALABAMA~~ Huntsville, Alabama.

"MAN AND FIREPOWER"

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Conference Report

FIFTH ANNUAL U.S. ARMY HUMAN FACTORS ENGINEERING CONFERENCE

22, 23, 24 September 1959

Redstone Arsenal, Alabama

I. INTRODUCTION

1. BACKGROUND

References:

a. Conference Report, "Army Human Engineering Conference," The Pentagon, 14-15 December 1955.

b. Report, "Second Annual Army Engineering Psychology Conference," Army Medical Research Laboratory, Ft. Knox, Kentucky, 7-9 November 1956.

c. Report, "Third Annual Army Human Factors Engineering Conference," Quartermaster Research and Engineering Command, Natick, Mass., 2-4 October, 1957.

d. Army Regulation 70-8, "Research and Development, Human Factors Research," 1 July 1958.

e. Report, "Fourth Annual Army Human Factors Engineering Conference," 9-11 September 1958, U.S. Army Chemical Center, Maryland.

Sponsorship and Planning of the Conference.

The Annual Army Human Factors Engineering Conference is sponsored by the Chief of Research and Development. Four such Annual Conferences have been previously held, and are reported by references a, b, c and e.

In accordance with reference d, planning for the Conference, as well as follow-up of its suggestions and recommendations, is accomplished by a Human Factors Engineering Committee. The Committee is composed of representatives of the Chief of Research and Development (Chairman), each of the Army Technical Services, and the U.S. Continental Army Command.

THE Purposes of ~~the Conference are:~~ THIS REPORT,

~~a.~~ To provide direct interchange of information on human factors engineering among personnel of Army development agencies, and between these and representatives of user agencies and other qualified individuals.

~~b.~~ To provide recommendations and suggestions to be followed up by the Army Human Factors Engineering Committee to assure exploitation of all opportunities for improving man-machine compatibility in the design of Army materiel.

~~c.~~ To provide a Conference Report which will serve as a useful and complete single compendium of all Army human factors engineering research and development activities.

The Conference was called to order in Rocket Auditorium, Redstone Arsenal, Alabama, at 0900 hours on 22 September 1959 by the General Conference Chairman, Dr. Lynn E. Baker, U.S. Army Chief Psychologist.

The invocation was pronounced by Major James H. Goewy, Post Chaplain, Redstone Arsenal, Alabama; after which the General Chairman introduced General John B. Medaris, Commanding General, U.S. Army Ordnance Missile Command, Host to the Conference.

2. WELCOMING ADDRESS by Major General J. B. Medaris, Commanding General, U.S. Army Ordnance Missile Command, Redstone Arsenal, Alabama

I would like to extend a very warm welcome to you this morning. The facilities and services of the Army Ordnance Missile Command are at your disposal, that your fifth conference may contribute substantially toward the solution of mutual future problems in this basic area.

The Age of Space in which we are rapidly advancing has introduced complex weapons systems and automation to a degree never before believed possible. In the popular conception the role of man has been reduced to that of a button pusher. After this initial stimulus, the machine reacts without human

direction or control, according to a previously installed program of action, or in response to delicately-sensed changing conditions.

Instead of shrinking into insignificance, however, the stature of man has been increased by the accelerating rate of scientific and technological advance. The human factor in man-and-machine relationships has received increasing attention in every phase of Army training, from the foot soldier to the crews for firing our most advanced guided missiles.

Nothing which science discovers or which technology devises can detract from the ultimate importance of the individual's role in our defense posture. To the infantryman, finally, we entrust the fate of our nation at those crucial times when the battlefield means life or death to him.

Every weapon, every piece of equipment, and every means of transportation or communication which we furnish him to enlarge his effectiveness should be tailored to his human capabilities and limitations. Our approach should be governed by a confident aim of full exploitation of his powers, however, rather than apprehensions on his limitations.

There is a tremendous untapped well of resources within the individual. It is our duty to learn how to develop and use these abilities to the fullest possible extent. Few individuals perform at peak capacity. Only by the full use of our resources, individually and as a nation, can we prepare for leadership in the world of today and of the future.

We are conscious of the human factor in the earliest stages of missile research. In trying to design and develop a missile which is best from both the technical and human factors standpoint, we cannot place the human engineer in a back-seat driver's position, and expect him to function through afterthought modifications of original designs. An unwavering approach to satisfy both goals is possible only if there is complete cooperation from the idea stage between the design engineer and the human engineer, each of whom must understand the other's problems.

The human engineer must be allowed to participate in the initial layout with the design engineer. He must be recognized as an equal partner to the fellow responsible for missile technical requirements. A successful design results when both the design engineer and the human engineer have been educated in the concept of system operation and are able to discuss and recognize that in some cases technical requirements are overriding and in others the human factors demand rules.

When this mutual recognition is reached, a design can be developed which will more fully meet the User's need.

Here at my Command, we are actively pursuing a course which will significantly improve man - machine matching with the result that the weapon system evolved will be effective in the hands of combat-ready troops in the field, as well as in the laboratory, where it is operated by engineers and skilled technicians.

Our short range program provides for use of the Human Engineering Laboratory of Aberdeen Proving Ground. HEL monitors the human engineering effort in each weapon system to assure that adequate and timely consideration is being given to the man-machine relationship. Steps have also been taken to insure that every component, end item, or system contract contains the approved human engineering clause.

For the long pull we are training Command personnel at all levels to perfect an in-house capability and insure that human factors are properly considered in the embryonic stages of missile development.

We feel that this program, vigorously pursued, will allow us to field a weapon system in which the man-machine relationship is developed to such an extent as to insure a more effective weapon system.

Let me leave this thought with you: Bold new thinking must transpire in this important area of man-machine relationships, in the days to come. We must develop our techniques so that man may feel as much at home in the strange new environment of the Space Age as he does in his terrestrial surroundings.

II. KEYNOTE ADDRESS

1. MAN AND FIREPOWER, address by Lieutenant General Arthur G. Trudeau, Chief, Research and Development, Department of the Army.

General Medaris, General Ely, Ladies and Gentlemen:

It is a great pleasure for me to welcome all visitors to this annual conference, and to join with those of you who are stationed here. My office is keenly interested in and vitally concerned with your programs and their impact on our weapons systems. So I extend the greetings of all of our people in the office of the Chief of Research and Development to you here today, and our best wishes for a profitable and enjoyable session.

Your theme, MAN AND FIREPOWER, embodies two of the most significant factors in our national defense equation. Certainly you could not have found two more divergent and opposing subjects from many points of view. On the battlefield the latter tends to destroy the former. Off the battlefield, in the disarmament discussions of statesmen and governments, the situation is reversed. Of course, your point of view is different yet. You must integrate the two factors to form a weapons system. One that allows the man -- the soldier -- to exploit fully his talents and his tactical opportunities on the field of battle.

It seems to be particularly appropriate to the conference theme that you are assembled here at the Army Ordnance Missile Command. Here, in the last decade, significant national and international contributions have been made in the field of rocketry and guided missiles, and it is through the talents and capabilities of the members of AOMC under General Medaris and Dr. von Braun that the Army looks for still more effective rocket weapons in the future. The proceedings of this conference, like the last four, should serve as vehicles for improved design of these weapons systems in terms of the human factors involved.

This morning I want to emphasize the vigorous and aggressive effort needed to make man the master of his weapons. I should first like to give you a few thoughts about today's battlefield environment as I see it; then discuss the Army's requirements and long range programs in the human factors area; and, finally, describe the action we all must take to achieve our objectives.

THE BATTLEFIELD ENVIRONMENT

The environment the soldier faces today is a severe one in every respect. The total and final nature of war, as it appears to many of the so-called experts, would seem to eliminate man and his chances for survival. They believe that the specter of a general war involving the long-range missile exchange of thermonuclear weapons, or the more conventional delivery by bomber aircraft, would be such a final action that ground forces would not be able to influence the results. In fact, the vision and fear of the detonation of nuclear weapons has so clouded the minds of many today that they can see no chance of the individual surviving such a holocaust.

However, in contrast to these views, the many studies, tests, and analyses of a nuclear war have shown that man can survive such a conflict although casualties may be heavy. Moreover, he can do it without any grossly harmful effects and still be effective as a fighting man in a ground unit. It was concluded that civilian populations can be protected in large measure against radiation and blast. Granted such protection, the nation as a whole could survive a nuclear war and, eventually recuperate.

We feel that the military population is in the same category: They can and will survive. The consensus of all of these studies is that man, the soldier on the battlefield, has become more important than ever before; albeit, the panorama of the battlefield itself will change.

Let me quote to you from a recent article on this subject is an authoritative Russian military journal.

"Use of these weapons not only does not abolish the conventional armed forces, but, on the contrary, leads to their augmentation.

" ... It is necessary to be oriented not toward an easy war but toward an extremely hard war which, during its entire course, will demand tremendous reinforcements for the armed forces.

"It is true that a contemporary war is a war of the physical, chemical and biological sciences, of the technical sciences, of science in general, but it is also true that a third World War, like all past wars but to a still greater degree, will be first and foremost a war of man."

In supporting this conclusion, we must recognize that one of the fundamentally important effects of the great increase in the range and destructiveness of modern

weapons is to make it essential to disperse forces on a wider scale and in comparatively small units. We have modified and are continually reviewing our tactical organizations to improve our capability to meet this requirement. We are constantly striving to improve our means of communications and battlefield mobility so as to permit the rapid concentration of our forces to exploit the blows of our weapons and effect their rapid dispersion again, before an enemy could react with blows of his own. We can expect that, much of the time, relatively small units will be operating independently or semi-independently.

In such a situation, infiltration by both sides will be fairly commonplace, with the result that there will no longer be a line of contact in the sense that we have known it up to now. Instead, there will be a deep battle zone in which units will find it necessary to operate in any direction.

Despite our improved communications, individual commanders of small units still will be expected to act promptly and vigorously on their own initiative in order to meet the threats which develop.

This places a premium on that combination of skill, judgment, determination, and character which is leadership.

However, the chances are greater than ever before that the individual soldier may be alone in an extensive sea of combat. He may not have the chance to lead others. The results of such a tactical situation may depend entirely on him, and others like him, and their weapons.

My point here is that each combat soldier, with his weapon, personally faces the enemy in almost any given situation. This peculiar nature of the Army's mission in war gives a unique urgency to the compatibility of the soldier and his weapon. And this man needs all the help that we can give him to prepare himself for combat, to carry a lethal, effective weapon, and to be willing and able to use this weapon to the fullest extent. These same principles apply to mortar crews, tank crews, gun sections and missile units to varying degrees. They apply to a soldier and his radio or a pilot and his plane.

I just mentioned that in the future combat environment the soldier may have to face the enemy essentially alone. Now just what do we know about this enemy from the human factors standpoint? This is as necessary a factor in your work as it is in planning any military program, for the enemy is certainly a part of the battlefield environment. Let me describe a few of the characteristics of this phase of the Soviet threat that will interest you.

The Sino-Soviet Bloc has a tremendous manpower potential upon which to draw for its military forces. As the technical nature of weapons and equipment progresses, the Soviets have demonstrated an increasing concern for developing skills which can permit the satisfactory operation and maintenance of that material.

Many of their military personnel are well educated in science and technology. This is emphasized at all levels. Higher education is extremely selective, and the curricula provide both fundamental science training, and a specialty in which the students are prepared for anticipated state needs. Institutions of Higher Education include 39 universities and approximately 380 institutions offering scientific and technical training and conducting research. The best equipment is contrated in institutes related to defense and heavy industrial development.

Granting that the Soviet soldier is well trained for his job, he has another advantage in his natural adaptibility to the rigors of the battlefield. Physical discomfort and the demands of military service are more like the normal way of life in the East than they are to the western individual, particularly the American. This permits a lower level of logistical support than in the West, as well as a lesser requirement for environmental training, to produce the same level of efficiency.

Let me now emphasize a few points about the manpower that we in the Army will have available in any future conflict.

The forces required for any conflict today, large or small, must be augmented by the citizen-soldier in the reserve forces and by untrained inductees. In addition -- and a point that we often overlook -- the Allied soldier will be participating alongside the U.S. combat man. Both of these soldiers -- the U.S. reserve soldier and the Allied soldier -- form an important segment of the Free World's manpower block. These men then have a decisive role to play in any military action, and their impact on the use of the Free World's firepower is obvious. We must consider their limitations and characteristics as much as possible in the integration of the soldier with his weapon.

As an example, the HONEST JOHN rocket, the CORPORAL ballistic missile, and the NIKE AJAX air defense missile system are already in the hands of allied soldiers. Has anyone made any investigations into the man-machine compatibility here? I would estimate that a great deal of interestinp and meaningful information could be garnered which would have a surprising effect on future military weapons. The pattern of U.S. military aid seems to be well established, so that much of our equipment will continue to assist other nations of the West in their defense against the inroads of communism.

Turning to the final portion of the battlefield environment that I will cover, we find the machines of war that often appear so incongruous to the tactical trends mentioned

earlier. You are all so well acquainted with the characteristics and requirements of today's complex weapons that I won't attempt to mention them. However, it occurs to me that we have outstripped ourselves so completely in this technological field that we are in danger of allowing the machine to become the master of the soldier.

We can never afford to let anything interfere with or inhibit the taking of a military objective, whether it be a hill or a large land mass. If the machine or weapon does interfere, it must be made compatible with the soldier. If it cannot be made compatible without reducing the battle efficiency of military organization, then it must be redesigned or discarded. There is no other solution. Perhaps we have many examples of this situation with us today. Our job is to uncover these by troop tests of equipment. It is better to reject a weapon system now because of operator failure than to find it rendered useless on the field of battle, perhaps exposing our forces to needless losses.

I have given you some of my thoughts on today's battlefield environment and the severe operating conditions to be expected. There are many obstacles to be overcome in linking the U.S. or Allied soldier with the weapons of today and with the more complicated machines of tomorrow. We may be forced to match this combination against the substantial man-and-machine power potential of the Sino-Soviet Bloc; a large measure of any successful result will be due to the efforts of you and your colleagues engaged in human factors studies.

HUMAN FACTORS REQUIREMENTS AND PROGRAMS

Now what are some of the requirements of human engineering in the firepower area, based on the environment that I have described?

Selection techniques must be developed to meet and anticipate special personnel requirements generated by new weapons systems. As one example, personnel must be selected to handle atomic munitions. The anticipated widespread distribution and general availability of atomic weapons will create a need for personnel who can remain effective during periods of great stress and continue to exercise a high order of judgment.

The increasing number and complexity of weapons and equipment is increasing the length and difficulty of training beyond acceptable limits. Research is needed to determine the minimum knowledge and skills required of the individual soldier, and to develop shorter and more effective combat and technical training programs. In this connection, the development of methods for the construction of shorter and more effective training programs is mandatory. Concurrently, means must be discovered to increase the degree of independence and autonomy of the soldier in his application of learned skills and knowledge.

Research must also provide objective proficiency tests to permit realistic appraisal of the effects of selection and training of individuals, crews, and units and the effects of troop compatibility with their equipment.

The development of successful predictors and indicators of the individual's behavior under stress and his effectiveness in combat is an urgent requirement. Morale and high fighting spirit must be assured in light of the effect of the use of atomic weapons and dispersion on the battlefield. Training techniques to prepare soldiers for the atomic battlefield environment must also be developed. In particular, methods must be discovered to innoculate troops against the potentially paralyzing effects of the nuclear battlefield. There will be a premium on leadership, initiative and courage never before equalled.

Training devices and simulators must be developed to permit repetitive, realistic and economical training in the complex equipment and expensive weapons systems in the Army. These devices must be sufficiently versatile to program a wide range of operational problems and malfunctions, and should be able to measure and record the proficiency of the personnel being tested.

Simulators employing modern computing techniques must be developed to simulate battlefield situations to provide command and staff training at all levels, from platoon through field Army. Only through the use of such techniques can the complexities and factors that may be involved in tactical operations of the future be presented to a large number of officers.

Research is necessary to establish the limits and forms of performance for sensory and motor functions that are important in human behavior. Increasing emphasis must be given to man-machine compatibility through equipment designs adhering to the principles of engineering psychology.

These have been some of the requirements in the firepower area. They are all real challenges complicated by the fact that some of the time-honored developmental procedures have to be altered. These are the cases where the human factor has been neglected, if not ignored. Perhaps there was a reason for this because of the inconsistent performance of the human being. Since we are not all alike, capabilities vary on a day-to-day basis, often in the same individual. This situation and others similar to it must be looked upon as incentives for all-out effort, and not as inflexible barriers to progress.

To meet these requirements, vigorous and prompt action through realistic programs is more important today than ever before. We

have some baffling obstacles to overcome, as you well know, and I cannot over-emphasize the dynamic effort needed to harness the impressive and complicated machines of war available for the soldier's use.

Many of you are intimately acquainted with these programs and have contributed to some of the solutions which are being employed. However, I should like to mention a few of the concrete results of this human engineering effort and highlight some of the areas that I believe deserve more emphasis.

HIGHLIGHTS FOR FURTHER EMPHASIS

As a primary example, these annual conferences have served to bring the technical services, Continental Army Command, or USCONARC, Department of the Army, the sister services and contractor personnel closer together.

Instructional courses such as the short course at McGill University, which will be reported on later on in the conference, are acquainting the hardware people with the thinking of the human factors engineers. On the other side of the coin, you will hear a report from the Army Scientific Advisory Panel Thursday morning as well as see the latest Research and Development film report.

This interchange of reports and similar documentary materials is an important source of ideas and information. In this area, I am also particularly pleased to mention the work of the Ordnance Corps as reflected in recent instructions which prescribe that human engineering will be done by professional human engineers on all Ordnance development and must be coordinated with the Ordnance Human Engineering Laboratories.

Here are a few of the results of our programs as applied to firepower.

Methods for reducing training time have been successful in various skill areas as electronics maintenance, tank crewmanship, automotive and aircraft maintenance and air defense system operation.

Some success has been realized in anticipating operator training requirements for air defense weapons systems, but less results are evident in anticipating mechanic and repairmen training requirements.

A number of new types of training devices and simulators are expected to facilitate training. These include a HAWK missile target simulator; a checkout and handling trainer for the SERGEANT missile; a tank-versus-tank Synthetic Gunnery Trainer that records target hits; and a Command and Staff Exercise Simulator which provides a means of training commanders and their staffs in their combat duties.

These are all significant and remarkable advances toward the goal of better trained men for better weapons, welded into an effective, combat weapons system. But we have just scratched the surface. We must probe more deeply into the man-machine relation so that we can be assured of more effective selection and assignment of our manpower. Then, this manpower must be distributed, organized and trained to enhance performance with the machine or weapon. And finally, continuous recognition must be given to the incorporation of human factors engineering in weapon hardware as it is developed.

In this last respect, I urge the technical services and USCONARC to give detailed attention to the human factors aspects in the development of materiel. It has recently come to my attention that 34% of the equipment delivered to the CONARC boards for tests is rejected. These rejected items should be examined to discover what proportion could have been avoided by proper attention to human engineering through all stages of development.

When I look over the roster of agencies represented here, and the activities in which they are engaged, I am pleased at the progress you have made in these four years. You have made a good start but you still have a long way to go in establishing a clear picture in the Army, and in supporting industry, of the nature and importance of your mission. There are two points that I would like you to think about in this connection: first, is that your conferences should indicate the important relation of human factors to HumRRO and its training mission, and to the Personnel Branch of the Adjutant General's Office and its task in the selection of personnel. Second, you seem to have an insufficient representation of industry at this conference. Industry must be made aware of the need for incorporating human factors design in more of its equipment destined for conversion from civilian to military use. Fully 90% of the Corps of Engineers development, for instance, is accomplished by industry and represents adaptation to Army use of commercial items.

Remember that, in the final analysis, all of your efforts and those of our entire research and development program are oriented toward giving the soldier the means to win by ground combat in any future conflict. Consequently, man <u>is</u> and <u>will remain</u> the most essential element in war. Men, not machines, win or lose the battle. In addition, the importance of the individual increases with the complexity of the weapons he must employ. This will be the case unless, and until, we reach the stage where we do have weapon systems that can logically reach a sound conclusion; that can withstand adversity; and that can match hardship and ability with devotion and courage to carry on to final victory. You and I will not live to see that day for there certainly are no such weapons on the horizon.

This soldier of today-and-tomorrow must still have much more than education and proper training for the complex equipment

that we must use today. He must still be made of the sterner stuff that carried our ancestors through the trials and tribulations of the past centuries' battlefields. He must still have the backbone, moral courage, and the vigor to survive, or to die if need be, and win in any combat area of the future. He must have a tenacity of purpose and the strength of will to overcome any adversity. He must be able to recognize the dangers that may occur in future combat and to make the proper decision under fire that has been the trademark of the well trained and disciplined soldier since the time of Alexander.

This is the man we are privileged to serve. This is the man to whom we dedicate our efforts and contributions so that he may survive and win on the field of battle.

2. INTERDEPENDENCE OF MAN AND FIREPOWER, address by Colonel Keith H. Ewbank, Assistant to the Deputy Chief of Staff for Materiel Developments, Headquarters, U. S. Continental Army Command.

The deterrence of war is a mission of our Army. To accomplish this mission we must be strong. Our strength must be such that a potential enemy knows that we can react quickly and deliver effective firepower. We must be able to hit fast and hard.

Throughout the history of warfare combatants have found that they must move, shoot and communicate with each other. Frequently smaller armies have defeated larger ones merely by superior ability. An important facet of leadership is the ability of the commander to train his subordinates to move and to shoot when he communicates his orders to do so. Success or failure in battle depends finally on the ability of man to do his job effectively in combat.

All of us recognize the fact that man is not only important, he is the key to success or failure in battle. I have heard General Patton describe the importance of man much more colorfully than I can. His vocabulary was larger than mine - and often unprintable. I quote a statement of General Patton's to show his feelings: "To win battles you do not beat weapons - you beat the soul of man -- of the enemy's man . . . To do that you have to destroy his weapons, but that is only incidental."

The art of warfare has progressed considerably from the days of the individual man fighting with clubs, through the bow and arrow stage, Hannibal's use of elephants as tanks, gunpowder, artillery, aircraft, mechanized devices such as heavily armored tanks, electronics, and atomic weapons. The Knight of King Arthur's day would be astounded at many of the weapons of today. However, an atomic weapon kills a man no more dead than did the lance and the sword. It does, though, take considerably more training and skill to use and maintain the weapons of today than the weapons of even the past century.

Those who make our new equipment strive to give us a better fighting capability with each new development. Sometimes we question the improvement. For example, I frequently wonder if our vehicle designers have not at times tried to make their product as rough as the horses I rode during my early years in the service. I am almost as tired at the end of the day's motor march as I was at the end of a day's march on the back of a horse. However, I find that we cover many more miles in a day using motors than we did using horses.

The many and varied items of equipment that we now use in our army depend on man to build and to operate them. Our fighting forces are only as effective as the ability of man to operate the varied items of equipment furnished.

An example of failure to effectively utilize manpower was the many wars of the crusades. The Christian knights of those days were individually very effective fighters. They were well mounted and well armed. They had the ability to defeat the individual Saracens whom they met in combat. The Christian forces generally were not welded into effective combat units and often lacked ability to communicate with other elements of their own fighting forces. The Christian forces usually lacked unity of command and failed to take advantage of their ability or even to recognize their need for effective intelligence. The result was the defeat of the Christian armies in each of the many crusades. The history of these wars taught very effectively that individuals must be welded into effective fighting units in order for them to win.

Each war develops new firepower capabilities with increased requirements for men to use such capabilities. Usually, after a war interest in developing increased means of delivering fire wanes. The Korean conflict taught us that, in the present critical situation, we must devote intensive efforts to developing weapons to enable us to fight more effectively. This, of course, must be a team effort by the developer and the user. However, the finest weapon for delivering firepower is only as good as the ability of man to use it.

To perform our combat mission most effectively we must wring from scientific knowledge every possible drop in order to obtain and operate good equipment. This equipment must be mechanically in an advanced state of the art but must be capable of being used effectively by an average man. We have insufficient holders of Masters and

Ph.D. degrees to provide such trained and skilled personnel to operate the equipment. We must depend on these highly skilled people to do the developing so that at least Mr. Average, and sometimes Mr. Below-Average, Man in skills can do the operation and maintenance. In the enthusiasm of the developer to wring the last drop from scientific knowledge we sometimes get the complex instead of the simple and the delicate item instead of the rugged.

Even though our machinery has become more and more complex through the period of years, we must constantly seek maximum simplicity to enable the front line soldier to operate his equipment in combat. There is a vast difference between operating electronic equipment in an air conditioned, relatively dust free room and in operating the same item of equipment in the desert or in the arctic. Each of us who plays a part in providing the machines for our fighting men must extend his efforts to providing maximum simplicity and ruggedness in order to achieve the best operational capability at the least effort in operation and maintenance. Of course, many of our user requirements impose a very great burden on the developer. For example, we would like a tank that is completely invulnerable to enemy fire. This, under present capability of armor, means a heavy tank in order to provide the armor protection. However, we would like that tank to be able to swim in the water. This means that the tank must either be light in comparison with its bulk or be a very bulky machine. We also insist that this tank be able to shoot great quantities of high explosive in order to destroy the enemy and also shoot hard enough and fast enough to knock out the many enemy tanks. This at the present time means that the tank must have either a very heavy gun or possibly a complex missile system. Neither solution appeals to us as the user. We also want this tank to be able to go across country through forests, mud and snow. We expect it to be able to keep up with light wheeled vehicles on the roads too, so it must be fast. There is no question but that the item that we, the user, desire most is beyond the ability of the developer to provide. The result is a compromise that does nothing as well as we want it done but yet will partially satisfy our many requirements. Unfortunately we find this same problem in almost every item we, the user, seek in order to improve our fighting ability. I suspect that the knights in the crusades had somewhat similar problems when they were selecting their horses and armor and lance and sword.

General Clarke, Commanding U. S. Continental Army Command, is responsible for determining the requirements for materiel for the Army in the field. Many people have many ideas regarding the needs of the Army. Our country cannot afford the cost of providing all the items that everyone feels that we need. It is obviously impractical to provide every soldier with his own vehicle. Also, an individual infantryman cannot possibly carry all the items of equipment that would be nice for him to have. It then is necessary for General Clarke to have requirements lists screened carefully to insure that essential items are retained and "nice to have" items are eliminated. Such screening action actually improves the capability of our combat forces within the means available.

In performing General Clark's responsibility for determining the suitability of items designed to increase our firepower capability, the seven USCONARC Boards perform user service tests. These tests are designed to determine if an item will perform as it should, under field conditions simulating combat conditions as nearly as possible, while being operated and maintained by average soldiers. Such tests are not infallible since they are subject to human error and to the fact that prototype items being tested sometimes differ from production items issued to troops. However, experience has shown that such testing generally weeds out the unsuitable and without such testing some unsatisfactory items are produced at considerable cost and are issued to using troops.

World War I was a war of position. The machine gun had made the defense supreme. Man stayed underground until a sufficient preponderance of firepower could be built up to enable him to blast his way through the enemy positions. In World War II the tank, the airplane, and the cross-country mobility of many vehicles restored considerable mobility to the battlefield. The tactical use of atomic weapons giving a few individuals great firepower capability, plus the increased mobility of our ground and air vehicles, will make World War III a war of dispersion and movement. We will expect to mass firepower rather than large forces of manpower.

Since we can expect World War III to be one of movement and dispersion, we must insure that our equipment can be operated and maintained frugally. We cannot logistically supply large quantities of fuel, ammunition, and spare parts. Neither can we afford long periods of time for field maintenance. We must be able at all times, day and night, to move, shoot, and communicate.

Regardless of our requirements to move and to communicate, our ability to win finally depends upon whether or not we can effectively bring sufficient firepower upon our enemy. Presently this firepower varies from the ability of an individual man to fire his rifle or other individual weapon to the megaton atomic weapon that may be delivered several hundred miles inside the enemy lines. Even though an enemy killed by an atomic weapon is no more dead than one shot by a pistol, the

atomic weapon can effectively cover a much greater area with its killing power. Both the pistol and the atomic weapon depend completely on the ability of man to select a proper target and to aim and direct the effect of the weapon on the enemy. So, regardless of whether or not the weapon covers only a small area of effect or a large area of effect, it is only as good as the ability of our soldiers to deliver its effect on an appropriate target.

Again I would like to point out that in these weapons for delivery of firepower we must seek maximum simplicity and ruggedness. And we must depend on representatives of the technical services, many of whom are assembled here, to insure that maximum effort is devoted to giving us equipment which we can use effectively in performing our combat mission.

You who are human engineers must devise ways to enable man to use his weapons more effectively and easily. You must realize that soldiers in combat are reacting under fatigue, fear, strain, and unfavorable environmental conditions, so equipment must be easy to use. To be effective, firepower must, above all, be responsive to the soldier. The man must have absolute control over where, when and how it is used.

I would like to end by quoting from a statement by General Bruce Clark: "The truth is that the most expensive weapon that technology can produce is worth not an iota more than the skill and the will of the man who uses it."

III. U.S. ARMY ORDNANCE CORPS PRESENTATIONS

1. "A HUMAN ENGINEERING EVALUATION OF THE SERGEANT TRANSPORT AND LOADING EQUIPMENT AND PROCEDURES", by Dr. Marvin Schneider, Research Psychologist, Ordnance Human Engineering Laboratories.

Ideally, human factors engineering (HFE) of complex missile systems is initiated concurrently with onset of missile concept-development, which progresses through two distinct stages. The first is the fundamental, prehardware, planning stage. It is here that HFE effort can accomplish most, where initial engineering design can incorporate sound human factors considerations prior to actual equipment development. The second phase of missile development is hardware fabrication and test. Here, during the test program, the missile system concept undergoes constant alteration. HFE must continually ride the current of this modification to insure that the weapon system will meet the military characteristics and tactical requirements of the military user.

Unfortunately, as we well know, it has been all too seldom that HFE has been included in primary system planning. Thus, the purpose of this paper will be to illustrate, in a limited case, the sustained process of accommodation of the second phase of system HFE. The paper describes a sequential field and laboratory study of the transport and loading equipment of the SERGEANT Missile System. It is hoped that it will exemplify the HFE product in one area of a multi-faceted system.

First, a brief history is in order. The SERGEANT Missile System incorporates inertial guidance, solid fuel propulsion, and high system mobility. The Firing Site equipment and one test van are shown in Fig. 1. The R&D prime contractor is the Jet Propulsion Laboratory (JPL), at Pasadena, California.

During September 1958, after a thorough study of the System, the Human Engineering Laboratory presented its proposed program of activity to the SERGEANT Steering Committee.

High on the list was evaluation of the transport and loading equipment, since missile loading is the most highly interactive, coordinated, operator activity within a system in which extremely fast, precise loading of a large missile is required. However, the original transport equipment was at that time being reevaluated by the JPL. Road test failures had shown inadequacy of standard Army vehicles to transport the motor section and therefore a new semi-trailer was in process of test and evaluation at the JPL. It was decided that the Human Engineering Evaluation of transport and loading would start immediately, though only the original equipment would be available for some time.

It may be wondered why work commenced at a point where a major equipment item was in process of analysis for possible replacement. But missile development is an interwoven, interdependent complex of hardware and functions. Final models cannot be awaited. Speed as well as flexibility is essential to success in the HFE endeavor, since design freeze of one component, or assembly, or function may obviate change of another. The earlier that modifications are suggested, the greater are their chances for incorporation.

Thus, in October of 1958, having received the fullest cooperation from JPL in providing the equipment and technician aid required, the Human Engineering Laboratory sent a 4-man team to Pasadena to study the equipment in two weeks of actual performance of all possible loading operations. The equipment utilized comprised: (1) Erector-Launcher, (2) an inert missile, (3) missile section containers, (4) the one new experimental semi-trailer available for transport of the guidance and motor sections, and (5) one standard Army 2-1/2 ton M-35 truck for transport of the warhead. Since the JPL anticipated that all missile sections would tactically be transported by and loaded from radically altered containers mounted only on semi-trailers, this set of equipment was certainly not standard, and already partially obsolete. However, the primary goals were to achieve familiarity with the problems associated with the loading operation, develop a loading procedure adapting human factors engineering principles to SERGEANT System characteristics, and to gain a thorough knowledge of Erector-Launcher mechanics and functions. This would later permit a full-scale evaluation as soon as the prototype tactical equipment became available. These primary objectives were accomplished, and a prototype loading procedure was evolved stressing speed, efficiency and safety, while reducing the number of operators previously used as the loading crew. In the process of familiarization and

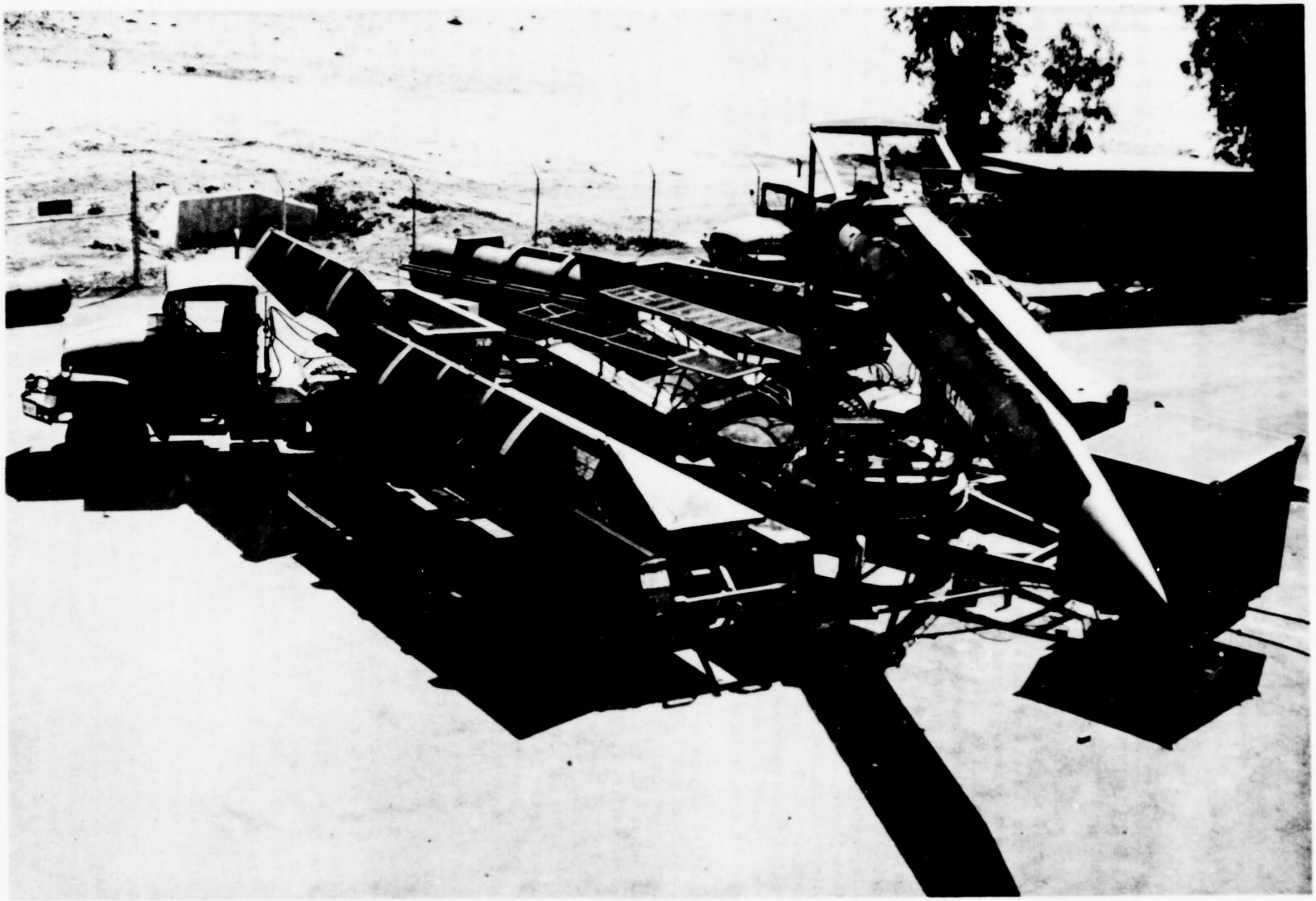

Figure 1. View of SERGEANT Missile System transport and loading equipment. (Test van is in background)

data gathering, the following two products emerged:

1. Specification of twelve human engineering deficiencies in the Launcher, and

2. Recommendations for solution of these deficiencies.

While this paper must be too brief to report all the inadequacies noted in the report, two examples should sketch the range involved.

a. Missile loading is accomplished through lifting of the missile section by a trolley on the Erector-Launcher (EL) boom (See Fig 2.). The sections are loaded from motor forward, attached to the boom and connected to one another. During motor loading however, the boom trolley must never be brought forward of a point slightly past the centrally located folding hinge in the boom. If this does occur, stresses become great enough to incur boom collapse, or to cause the Erector-Launcher to overturn. Either would result in an aborted mission; the dropping of a live motor would incur an added danger, and probability of operator injury would be high. In either case, damage to the EL would probably be extensive and possibly result in loss of this major piece of equipment. The critical point on the boom was marked by a painted yellow-line. This, however, is almost impossible for the boom operator to see because of his position. Its use is to guide the other crewmen in directing the boom operator. However, a painted line is difficult to see in snow, rain, fog or night operations, and communication problems are intensified in these situations. Further, the human factors engineer cannot ignore the everpresent human limitation of forgetfulness, which, in this case, would be disastrous. Therefore, it was strongly recommended that an automatic interlock be inserted in the system, such that forward movement of the trolley past the critical point on the boom would be possible only on manual override by a separate control. This would incur almost no increase in loading time, since its use would be necessitated only once during each missile loading. It was further suggested that if other factors obviated this completely automatic solution, a suitable auditory warning system (of sufficient intensity to overcome turbine, pump and other masking noises) would constitute an acceptable, though less desirable, alternative.

b. In contrast to the obviously disabling character of the inadequacy just described, a number of less obvious, but nevertheless tactically important deficiencies were also revealed. An example of this may be seen in the Launcher dust covers. The unattached, plastic dust covers protecting the umbilical plugs on the Erector-Launcher were considered inadequate. While light, and faster to use than screw-on caps, they are subject to frequent misplacement or loss, leaving crucial plugs unprotected. The Human Engineering Laboratory recommended snap-on plastic caps, with an inner ring for good seal, connected to the Launcher by metal chain. This type of cover was also considered applicable for external plugs on the Firing Station and the two associated test vans.

As soon as this evaluation was completed, prints were obtained of the construction of the new semi-trailers and anticipated transport containers. From these drawings, functional models of missile, Erector-Launcher, semi-trailers and containers were constructed to a one-tenth (1/10) scale. The purpose of these models was to enable development of a loading procedure (following the Human Engineering Laboratory prototype) created from its inception to meet the needs of the new equipment.

Some further clarification may be helpful at this point of the reason for the effort expended with these models. One of the major objectives of the Human Engineering Laboratory is to aid in development of the most effective, efficient hardware this country can produce. But to evaluate complex equipment and recommend redesign directions or specifications it is necessary to utilize the equipment with as near optimum tactical procedures as can be accomplished. For inefficient use of a piece of equipment may cause it to appear inadequate, while the most proficient use can render a weapon adequate which is relatively difficult for operators to handle. In the case of a missile system, with several vehicles, the same is true of a vehicle loading arrangement. Vehicular placement is an extremely important determiner of loading time, difficulty, and safety when total available loading time is extremely short. With a less than optimum vehicle location, excessive jockeying will occur in positioning of the semi-trailers . . . which can be a very time consuming operation. Time may also be lost if operators need to jump to the ground in moving between semi-trailers and the Erector-Launcher. They may be required to move beneath the loaded boom, at times containing unbolted sections . . . a definite safety hazard. The arrangement may also force unnecessary avoidance of open container lids by the partially loaded boom . . . costly in time and effort.

The vehicle and Erector-Launcher arrangement demonstrated by JPL during the February 1959 Design Release Inspection, which utilized the new semi-trailers and missile section containers, was considered by the Human Engineering Laboratory to contain several serious problems. These were: (1) warhead had to be lifted from its container at an angle greater than 130° from its terminal direction when locked to the boom. The resulting twist put on the trolley cables (arbitrarily set by JPL at a safety maximum of 90°) increased tension past desired limits

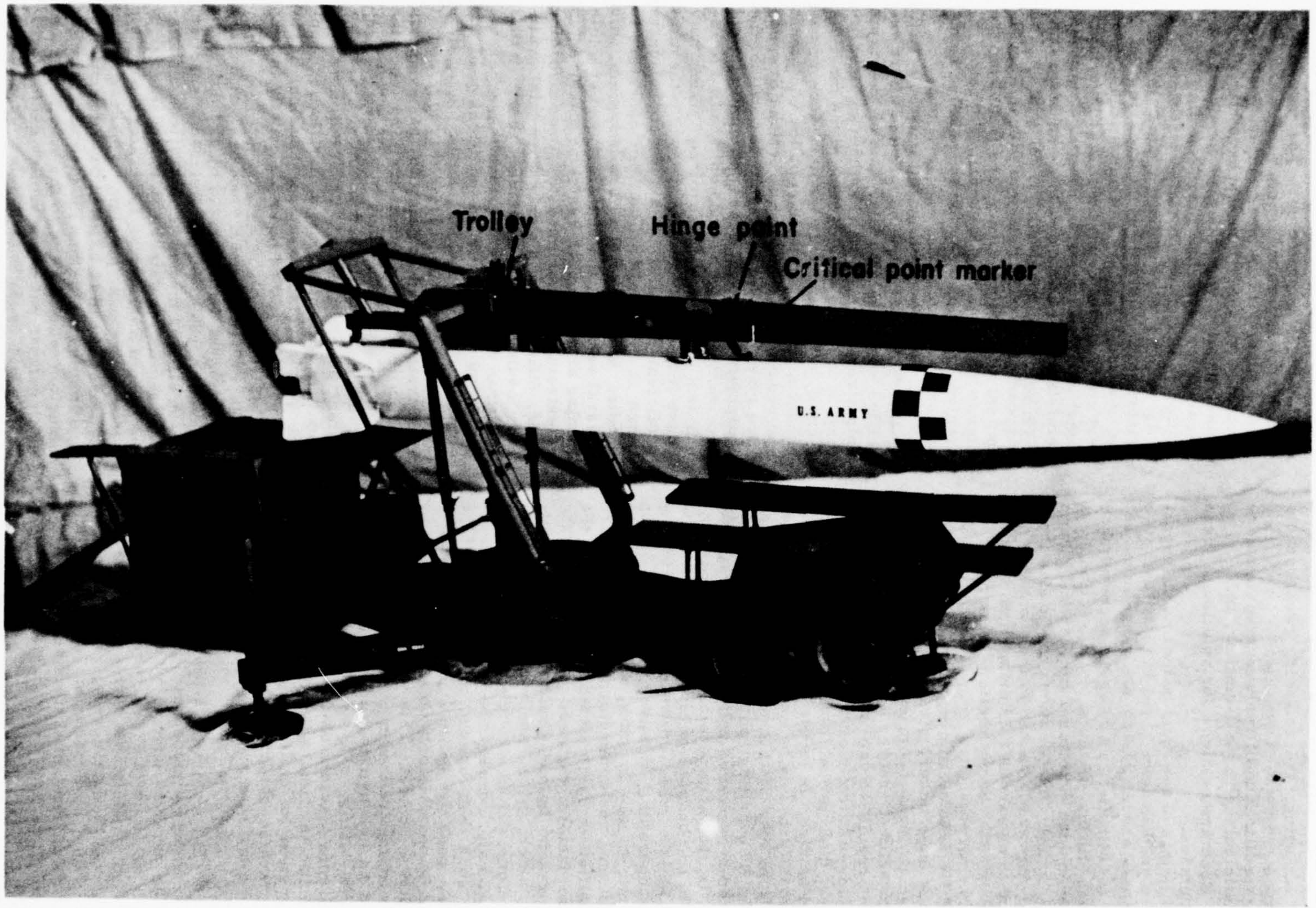

Figure 2. Model of Erector-Launcher and Missile.

for continued use as would occur with an Erector-Launcher used for practice as well as firing, (2) the semi-trailer mounting the warhead containers was required (because of its location) to be moved during loading of the warhead, and (3) the distance between the warhead semi-trailer and the Erector-Launcher required the section-handling operators to move from atop the Erector-Launcher and semi-trailer to the ground and back several times.

For these reasons a detailed analysis was performed at the Human Engineering Laboratory with the scale models to evolve the most practical and efficient vehicular arrangement, and based on this arrangement, loading procedures for the new equipment. Without complete familiarity with the obsolete equipment and previous procedures, however, reliable or fruitful work with the models would have been impossible.

The vehicular arrangement derived through the use of the models is shown in Fig. 3. It permits: (1) loading of either warhead at less than a 45° angle from the terminal direction on the boom, (2) extremely simple initial positioning and maintenance of one position of the warhead semi-trailer throughout loading, and (3) free access between the warhead semi-trailer and Erector-Launcher without necessity for operators jumping to the ground.

The next phase of the transport and loading evaluation was accomplished at the JPL during February and March 1959 when the Human Engineering Laboratory conducted a major field study. The field study which used representative user-type personnel and final experimental launcher equipment was designed to: (1) evaluate and verify the vehicular loading arrangement and the conceptual loading procedures evolved within the Laboratory, (2) uncover any additional human factors engineering deficiencies in the transport and loading equipment, (3) provide data with which at least some evaluation could be attempted of the adequacy of the transport and loading equipment to do its job in accordance with the System's Military Characteristics.

Eleven enlisted men and an officer were used for the study. The EM had completed basic training and were assigned to artillery units, but had no previous missile training. Complete background and test records on the men showed them representative of anticipated future SERGEANT users.

The men were given orientation lectures on the general nature of the System, shown films of loadings, and given two loading demonstrations. They were then assigned to one of two crews and, after brief tests, assigned operator positions, and trained according to the procedure developed by the Human Engineering Laboratory using the Laboratory models.

During this orientation period, the Human Engineering Laboratory personnel moved the vehicles (Erector-Launcher and semi-trailers) into several different arrangements to verify empirically the theoretical results of the Laboratory model study.

Following training, each crew performed a number of complete missile loadings. These loadings were evaluated by time, motion, and error criteria. Photographic and interview techniques were also used to supplement the evaluation in terms of equipment deficiencies, man-machine incompatibilities, etc. In terms of vehicle arrangement and loading procedures this field study in all essentials verified the work done with scale models at the Human Engineering Laboratory.

With respect to equipment deficiencies uncovered during this field study, 26 Human Factors problems were isolated. With a view toward brevity, none of these will be reviewed separately; rather, the general areas of difficulty will be cited with indications of solutions.

1. The first major area involved inadequacies affecting human efficiency during loading. These included lacks or deficiencies in personnel support surfaces, equipment handling devices and in safety and means of movement of personnel. Recommendations for solutions cited: (a) installation, widening or extension of work platforms, (b) design for reversible alteration of ladders to vary depth of foot space on rungs, (c) installation of handgrips and improvement of handling aids, (d) lining of hot surfaces, (e) varied resurfacing of metal sections used for walking or working, and (f) redesign to reduce foot wedging and consequent dangerous falls.

2. A second major source of difficulties involved inadequacies associated with inefficient functioning or location of equipment. These resulted in unreliability of operation leading to time loss and possible equipment inactivation. Recommendations cited: (a) redesign of missile section seating and locking assembly, (b) design for nozzle plate positioning aid, (c) protection of controls from inadvertent activation and environmental conditions, (d) specification of an unsafe warhead retaining-band lock, (e) container motor-securing pin reshaping, (f) redesign of unreliable buckles on motor and warhead retaining belts, (g) hydraulic pipe and hose relocations to prevent damage by operators, and (h) recommendations necessary to permit duplication of function for use of fewer wrenches by loading crewmen.

Initially it was stated that HFE should begin with concept development. However, in practice, HFE is usually included somewhere during the hardware development stage. While this is unfortunate, it is nonetheless a reality, and hence requires that the human factors engineer be adaptable and skillful in attempting to overcome the time lag so created. This paper has attempted to show one method of accommodating Human Factors Engineering

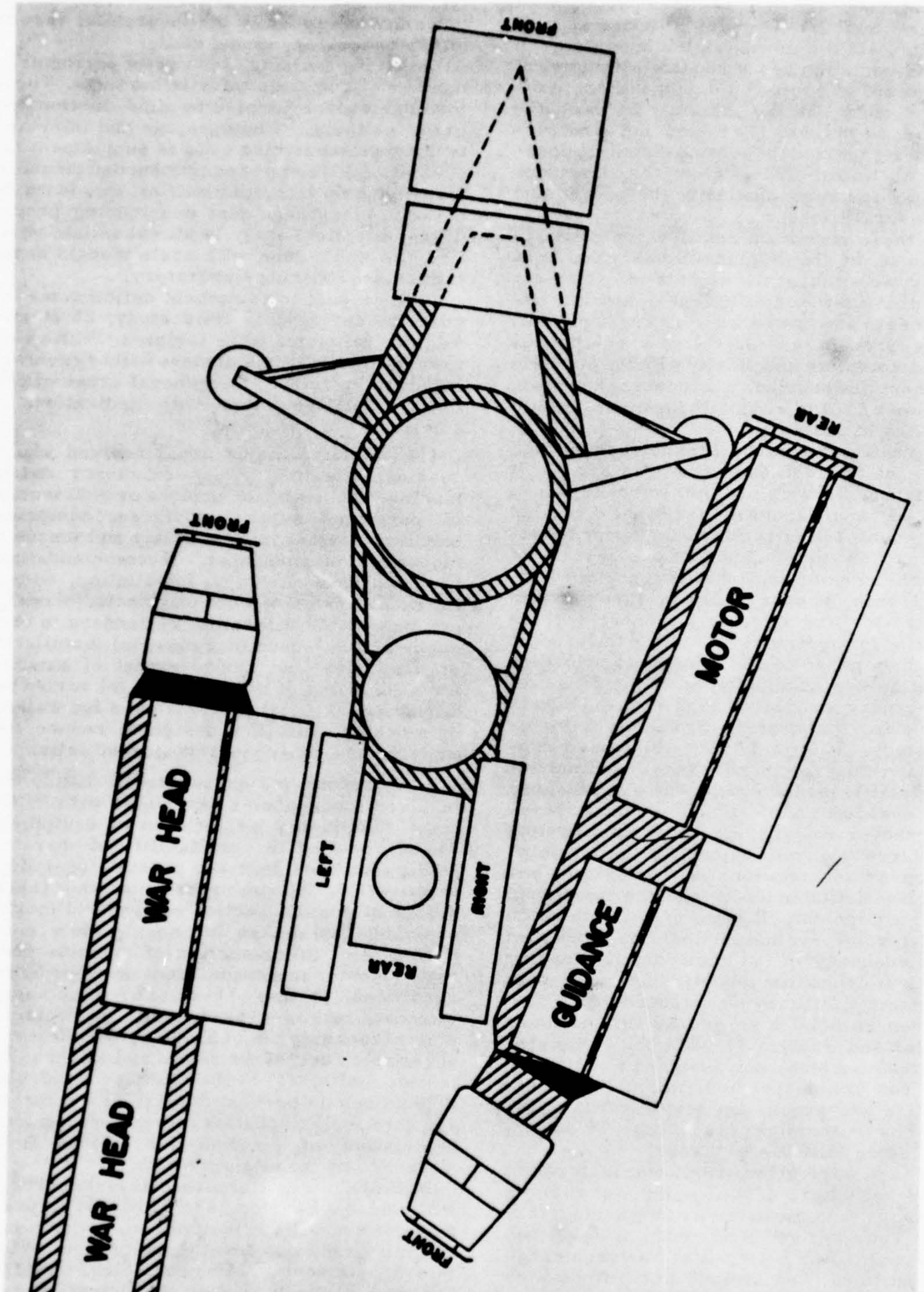

Figure 3. Human Engineering Laboratory preferred vehicle arrangement.

requirements and consideration through (1) complete understanding of the System requirements and anticipated operations, (2) the application of this knowledge to conceptual operational studies using scale models to derive needed data, and (3) the conducting of major field studies employing user personnel in order to isolate final inadequacies in the equipment and conceptually derived procedures, as well as to provide an overall evaluation of the System's ability to meet the demands of its military requirements.

2. Abstract (Unclassified) of SECRET Presentation: "HUMAN FACTORS IN THE DESIGN OF RANGE-FINDING DEVICES" by Albert A. Glass, Chief, Human Engineering Unit, Picatinny Arsenal.

Introduction

In any discussion of "Man and Firepower" a good deal of consideration must necessarily be given to accurate direction of that firepower. In an attempt to arm the fighting man, research and development has produced many unique and promising weapons. However, too often, the research and development of the weapon concept has not adequately solved the problem of enabling the weapon's operator precisely to locate the target.

The prospect of limited warfare and the Pentomic concept give key emphasis to the firepower of small, integrated groups. It is probable that tomorrow's battlefield will see the engagement of fluid, highly-mobile units, which will be forced to engage the enemy and protect themselves against attacks without higher-echelon support. Moreover, future warfare will probably contain extensive night tactics and hit-and-run encounters. With these conditions in mind, and in view of the cost of some of the advanced weaponry, a good deal of concern is being generated for weapon and method developments which emphasize higher probability-of-kill and first-round accuracy.

Missile systems utilize a number of sophisticated range-determination methods, most of which depend upon known target coordinates, fixed installations and extensive computations. Traditional artillery has generally satisfied its ranging problems through the use of long-base rangefinders, fire-direction centers, registration fires, or such methods as "bracketing" and "walking-up" to a target.

However, the ranging methods applicable to traditional artillery are not often appropriate for most of the more recent weapons. These new weapons are often fired in high trajectories and require exact range information. However, their maximum effectiveness is in the close-to-medium ranges and they may be shoulder-fired or of a highly-mobile, team-type variety. To date, little confidence has been developed in range-finding devices in connection with these weapons.

Rangefinding

To make rangefinder usage worthwhile, any negative aspects which it introduces into the weapon system must be more than compensated by advantages. For example, in using a rangefinder the time between spotting the target and firing will be increased. This results in a loss of efficiency which must be compensated for by an increase in accuracy. Any existing rangefinding apparatus involves limitations. For each particular weapon system, it must be determined what sacrifice can be tolerated and what improvements in accuracy and precision will be gained.

Essentially, there are three common types of rangefinders in use. All of them depend upon the principle of triangulation for range determination. In the self-contained, optical rangefinders, such as the coincidence and stereoscopic instruments, the base of the triangle is the optical distance between the end reflectors at each end of the tube; the target is the apex of the triangle. If the base length is relatively short and a target is viewed at a relatively long distance, it is easy to conceive that the angle subtended at the base of the rangefinder will be too small to provide for accurate determination of the range. This is why longer baseline rangefinders are generally more accurate. The rays of light are received from the target by the reflectors and directed outwards through a single eyepiece in the coincidence type. One eye sees two partial views of the target, one above and the other below a fine separating line. These two views are brought into alignment by fine adjustment of the prisms. In the stereoscopic type, the difference occurs when the prism reflectors direct the light rays separately into the two eyes. In each of the two fields there is a mark. The range is taken by means of adjustment until the target and mark appear to be at the same distance.

The stadiametric rangefinder has an external baseline which is the width of the target. The range is determined by the measurement of the angle subtended by the target at the rangefinder. Because the stadiametric rangefinder has an external baseline, it can be made smaller than other optical ranging instruments.

How good are these instruments? In the case of the stadiametric device the range error would be zero *if* the target dimension perpendicular to the rangefinder were known. In many instances the target dimension must be estimated, providing the most serious source of error. This is particularly true, as

a recent study has indicated, if parts of the target are hidden. However, even in those cases where the width of the target is known exactly, the target obliquity error may contribute greatly to the total error. This occurs when the target is not sitting normal to the plane of the rangefinder. In other words, one side of the target is closer to the rangefinder than is the other side.

In the case of the coincidence instrument as compared to the stereoscopic rangefinder, there has been a general feeling that the coincidence type is preferable. It is generally conceded that the ability to induce stereoscopic vision is reduced in the stress of combat. It is known, too, that a majority of individuals cannot induce stereoscopic vision and that the ability to do so is reduced with age. Finally, the ease of training and speed of operation favor the coincidence instrument.

A study by HumRRO in comparing the stereoscopic rangefinder with a coincidence rangefinder, found that whereas only 15% of the subjects could use the stereoscopic device, all of the subjects could use the coincidence instrument. A second study of 120 men given five weeks of rangefinder training with a stereoscopic device, indicated that only 10% of the subjects met or bettered the prescribed standard of accuracy. An ORO study comparing visual estimates of range and a stadiametric and a coincidence rangefinder, concluded that for disappearing targets, both the stadiametric and coincidence rangefinders were no better, and probably somewhat worse, than unaided visual estimations of range. A British study concerned with the choice of a new anti-tank weapon, compared visual range estimation with rangefinder determination of range. An error of 25% of the true range was found for visual, unaided estimation of range and an error of 15% for the rangefinder. The target was not less than 500 yards away and was both stationary and moving at 10 miles per hour. Finally, it has been found virtually impossible to make good coincidence on a moving target, or on indistinct targets, and that there is a very large bias error at greater ranges for the stereoscopic instrument.

There is a definite size and weight problem with self-contained ranging instruments. It is conceded that optical development is at a stage to the extent that an 18-inch baseline is a definite minimum for an inherent ranging error of 10%, or less.

3. "AOMC HUMAN FACTORS ENGINEERING" by Mr. Donald I. Graham, U.S. Army Rocket and Guided Missile Agency, Redstone Arsenal.

In developing the complex weapons systems of the space age, the Army Ordnance Missile Command realizes the importance of Human Factors Engineering. The Command feels that in order to obtain full benefit from a human engineering program it must be established at the design level with participation in the initial layout and development of weapons system. In order to translate this policy into action, AOMC has established a program to implement Ordnance Corps Technical Instruction 200-1-59. Consequently, under this program the CG of AOMC is responsible for policy and control over human factors engineering, but the specific implementing actions required by this OCTI have been assigned to Army Ballistic Missile Agency, Army Rocket and Guided Missile Agency, and White Sands Missile Range.

We are all well aware of the serious shortage of qualified manpower that exists in the human engineering field. The Command has also taken steps to alleviate this problem. We are in the process of selecting individuals from Army Rocket and Guided Missile Agency and Army Ballistic Missile Agency for training in the field of human engineering. When the selection process is completed, these individuals will be sent to the Human Engineering Lab at Aberdeen Proving Grounds for training. The period of training will vary so as to be mutually agreeable to both organizations. It is believed that this will be a means for at least somewhat relieving the existing shortage of personnel. It is recommended that such courses should be tied in with Army training programs in such a manner that college credit will result.

OCTI 200-1-59 stipulates that each component, end item, or system contract contain the approved human factors clause. In connection with this, AOMC is encouraged to see that the adopted clause is essentially one which ARGMA has been utilizing since 1955. We feel that these clauses have served several very useful purposes:

First - The clauses have required the contractors to concern themselves with human engineering. Some have performed this work by hiring their own human engineers, while others have contracted for such consultive effort.

Secondly - The man-machine relationship receives deliberate study early in the design and development effort, and not as an afterthought. This has tended materially to improve missile system usability for the ultimate consumer - USCONARC.

Thirdly - It has involved money and effort and has, therefore, removed human engineering from a nice play on words, to a specifically recognized and important activity. We believe that this proper and timely application of study and effort has materially improved the man-machine

relationship in the Army's guided missile systems.

The Army Rocket and Guided Missile Agency has accomplished the monitoring of the contractor's human engineering effort by utilizing the Ordnance Human Engineering Laboratories, (HEL). Each individual missile project has funded HEL for this effort on a fiscal year basis, so they literally have been contractors to ARGMA.

This approach to the problem has been of benefit to ARGMA and to HEL in several ways:

a. It has enabled this agency to monitor the contractor's effort in the human engineering field to assure that adequate and timely consideration was being given to the man-machine relationship.

b. It has enabled HEL to become intimately acquainted with missile systems in a manner which would have been otherwise impossible.

c. It has permitted assistance to be provided to our contractors in fields where they could not be expected to have specialized competence. An example of this can be given in PPI scopes, wherein over the years the various symbols being used had become confused, to say the least. Now if we had asked one contractor to state which symbols were best, we could expect that he might respond in the human manner, namely, that his were best. We might expect a similar answer from any other contractor that we might ask.

However, no specific study had previously been made as to the best shape, size, light intensity, etc., for such symbols. The strongest control of the type symbol to be used up to that time seemed to have been determined somewhat by what symbols could easily be generated by associated equipment.

Therefore, HEL was funded to make a specific study to determine which symbols of all those in use were considered best. This was a typical study involving equipment, technological capabilities, personal preferences of trained operators, controlled conditions, etc.

The study resulted in a series of symbols which could be readily recognized, were less subject to confusion under stress and could be generated by all missile systems needing such symbols. The results, provided to the contractors, as an outgrowth of a careful study that was discussed ahead of time with the contractors, by a competent, unbiased agency of the Government were, of course, much more palatable to the contractors than if the results had been developed by one of their competitors.

The Army Ballistic Missile Agency has had personnel from the Ordnance Human Engineering Laboratories here at the arsenal working with ABMA design groups on the launching and handling vehicles and concepts pertaining to the REDSTONE, JUPITER, and PERSHING systems.

In the REDSTONE SYSTEM a modest application was made of human engineering techniques to the design, development, evaluation and product improvement phases of the missile system program. Through a subcontractor effort, a consulting firm performed a study to develop human factors design guidance for application to fire control and checkout vehicles. Following the prototype design, reviews of drawings and equipment were performed by human factors analysis groups. But at that early time in the evaluation of missilry, concepts of human factors engineering application were in their infancy. We were, as we still are, just learning. One valuable lesson brought home to the REDSTONE development personnel was the recognition that even in a rush program, full application of human factors engineering principles can result only when a human engineering program is established early in the design phase.

The fullest application of human engineering participation in design and development was reached in the JUPITER system. Some of the more significant aspects were:

1. Early integration of human factors effort into the program by personnel from the HEL, Aberdeen Proving Ground.

2. Establishment of a requirement that the system Prime Contractor provide human engineering effort in assigned phases of the program.

3. Required participation by HEL personnel in layout and design of equipment, work spaces and procedures.

4. The establishment and design of visual display requirements for system checkout, monitoring and operation.

5. Development of an area lighting system featuring low intensity sources to overcome glare and to preserve, to the maximum extent, night vision adaptation of the personnel while still providing illumination levels sufficiently high for task performance.

(While on the subject of lighting, it is important to note that considerable study has also been made of the possible application of infrared lighting principles for night operation for various field type missile systems. To use infrared lights, infrared reflective tapes, etc., could actually highlight the vehicles for reconnaissance planes using infrared sensitive film. Thus the infrared highlighting principle was considered inappropriate.)

In the case of the PERSHING Missile system program, a similar attempt is being carried out to achieve a suitable input of human factors during the design phase. In this case, the contractor is doing the major portion of the design effort and HEL personnel from Aberdeen are utilized for assisting ABMA in evaluating and approving the results

of the contractor. They are also available on a consulting basis during contractor design, development and evaluation effort.

At White Sands Missile Range, many of the missile systems under the technical control of AOMC have been given the R&D, as well as Engineer-user, tests. In several instances these tests have provided the opportunity to study the man-machine compatability. Representative troop-type personnel have been trained ahead of time on the SOP for the system. They have then operated the system itself under simulated field conditions. Such studies of the SOP as well as the ability of personnel to perform the expected functions, have enabled changes to be made in the early R&D phase prior to the production of Prototype systems. This is another means whereby the Ordnance Corps is endeavoring to provide the user, CONARC, with better and more usable missile systems.

Thus, while much has been accomplished to date in this field of Human Factors Engineering - we of AOMC expect to accomplish even more in the future - so that the Ordnance Corps will provide the best equipment in the world - for the Best Troops in the World.

4. Abstract (UNCL) of CONFIDENTIAL Presentation: "SIGNAL DETECTION ON AN A-SCOPE" by J. R. Melville, Bell Telephone Laboratories.

This paper describes a study of signal detection on an A-scope. Its purpose was to investigate the increase in signal-to-noise ratio required for detection due to displacement of the signal from the observer's point of visual fixation.

Observers viewed a 5-inch A-scope display. Signals at different signal-to-noise ratios could appear at any one of four locations along the horizontal trace. The task of the observer was to report the location at which signals appeared. The signal points were at about 0, 6, 11, and 17 degrees (visual angle) from the observer's point of fixation.

The results indicated that the signal-to-noise ratio required for signal detection increases with increasing visual angle. The ratio must be about 2 db greater for signals at 17 degrees from the fixation point than for those at fixation.

5. Abstract (UNCL) of SECRET Presentation: "HUMAN FACTORS IN OPTIMIZATION OF THE REDEYE WEAPON SYSTEM", by Mr. Earl B. Gardner, Operations Research Group, Convair Division, General Dynamics Corporation.

REDEYE is a shoulder-launched antiaircraft guided missile, designed to be used by one man or in a team.

Target detection, acquisition and tracking, and missile warm-up and firing are all accomplished by the gunner, aided only by elements of his weapon designed for the purpose. These elements of the weapon, together with the gripstock, shoulder rest, and safety devices are being designed to optimize the effectiveness of the weapon system which includes the man as a major factor.

The paper discusses a number of human factors problems which have been solved, some in the process of solution, and others yet to be undertaken.

6. Abstract (UNCL) of SECRET Presentation: "APPLICATION OF HUMAN FACTORS ENGINEERING TO THE HAWK SYSTEM," by Mr. Lawrence Pitman, Raytheon Corporation.

The intent of the paper is to emphasize the need for concurrent human engineering effort in a modern weapons system R&D Program, with HAWK being discussed as a particular example. Emphasis is on the fire control aspect, although other topics are discussed.

The system is described as it now is, to give a proper background for the remainder of the discussion. Then the problems presented in HAWK fire control design, the methods of attack, and the results are discussed in some detail.

The chief problem in HAWK was the minimization of system response time, due to the primary low altitude mission and the ensuing short warning times.

Two methods that suggested themselves, complete automation, and man plus electronics, were considered, and the latter was chosen because of HAWK mobility and major item weight-limit requirements. Proceeding on this basis, and with the system radar data inputs known, a paper design was made of the Battery Control Center, working in conjunction with Dunlap and Associates, the HAWK human engineering subcontractor. The initial design was run through tactical games and studied from the hardware feasibility aspects. A paper redesign was made based

on finding from the studies. After iteration of this process, a design believed to be suitable resulted. This was breadboarded, evaluated with human operators, and necessary design changes made. A full scale engineering model was then built and evaluated in conjunction with the rest of the HAWK system. Final design modifications were then made and a production prototype was built. A final human factors evaluation was made on this prototype and changes required were made prior to release of the design for volume production.

The results of this design procedure are described in some detail, and a typical engagement sequence is presented.

Other aspects of human factors applications to HAWK are described, such as launcher loading method choice, battery set up studies, and others.

7. Abstract (UNCL) of SECRET Presentation: "HOW MOCKUPS AND USE OF REPRESENTATIVE TROOP-TYPE PERSONNEL IMPROVE HUMAN FACTORS ENGINEERING," by Maurice A. Larue, The Martin Company, Orlando, Florida.

The use of mockups and representative troop-type personnel does more than merely improve human factors engineering. These tools are as essential to the human factors specialist as the breadboard is to the electronics engineer. If these tools are not utilized in the design of a system, costly redesign and retrofit programs result, or equipment is sent to the field which is incompatible with the personnel assigned to operate and maintain it. If the use of these tools is used in the design - and phased in at the proper time - the resultant system is less prone to redesign and retrofit, and a more effective and efficient system results.

IV. U.S. ARMY MEDICAL SERVICE PRESENTATIONS

1. "THE ACOUSTIC REFLEX AS A PROTECTIVE MECHANISM FOR FIRING NOISE," by Captain John L. Fletcher, MSC,* Psychology Division, U. S. Army Medical Research Laboratory.

Noise-induced hearing loss is an expensive problem that has faced the Armed Forces for a long time. It is expensive in many ways. Trained personnel in critically short supply frequently must be removed from noisy jobs which require normal hearing; pilots are an example of this. Hearing loss also serves to reduce efficiency and causes errors that may be costly. Another cost to the Armed Forces of noise-induced hearing loss is compensation, either through the Veteran's Administration, or through retirement for medical disability.

Military noise exposure is primarily of two types. Vehicle engine noise and track noise are steady state noises that are frequently found at levels sufficient to induce permanent hearing losses if exposure is prolonged. This aspect of the problem has been attacked through use of conventional ear protective devices (earplugs) and hearing conservation programs. Another important source of hazardous noise exposure is gunfire or impulsive noise. Our laboratory currently has a research program, one of the interests of which is studying the effects of gunfire on hearing, and discovering appropriate means for protecting military personnel from these effects.

We have long known that there are two muscles in the human middle ear which, when activated, serve to attenuate or reduce the amount of sound transmitted from the middle ear into the inner ear. These muscles, tensor tympani and stapedius, apparently act to lessen the transmission of sound by the ossicles or temporal bones. The contraction of these muscles constitutes the acoustic reflex response. However, it takes these muscles at least nine milliseconds to make this response to sound entering the ear; gunfire sound has already done its damage by the time the muscles can respond. Therefore, in order to utilize the protective action of these muscles, some way should be found to activate the muscles before the noise occurs, in order that they be already in a contracted state when the impulse sound impinges upon the ear.

Previous studies have indicated that the function of these muscles is protective, but these data were taken from animals that had been stimulated electrically or mechanically. Generalization from results of past studies directly to humans would be tenuous, so an experiment was designed to evaluate the protective effect on humans of the acoustic reflex contraction in the presence of impulse or firing noise.

Direct assessment of the auditory protection afforded by the reflex requires the presentation of a traumatizing acoustic stimulus independent of reflex action, and a similar presentation in the presence of such action. Impulsive sounds such as those arising from gunshots and metal stamping machines have long been known to produce acoustic trauma, and because of their rapid rise time (less than two milliseconds), to create their trauma before the reflex is activated. Therefore, impulsive sounds provide a suitable means for investigating reflex protection. It remains, then, to compare acoustic trauma as measured by an immediate temporary threshold shift produced in the absence of the reflex, with that produced in like manner but with the reflex functioning. Threshold shift is the decrease in auditory acuity which follows exposure to loud noise. After sufficient time has elapsed, acuity usually improves; thus the shift is temporary.

A schematic diagram of the normal temporal sequence of impulse noise, reflex contraction, and input to the inner ear as we visualize it, is shown in the first part of Figure 1. The second part of Figure 1 depicts the reflex triggering tone, reflex contraction, impulse noise, and input to the inner ear as we believe it might occur under proper conditions.

A convenient, readily available device for the presentation of repeated impulse noises is the .30 caliber machine gun. It is easily triggered by a solenoid and produces sound pressure levels of sufficient intensity to induce a temporary threshold shift. Such a device, modified for use with blank rounds, was assembled and placed in the anteroom of

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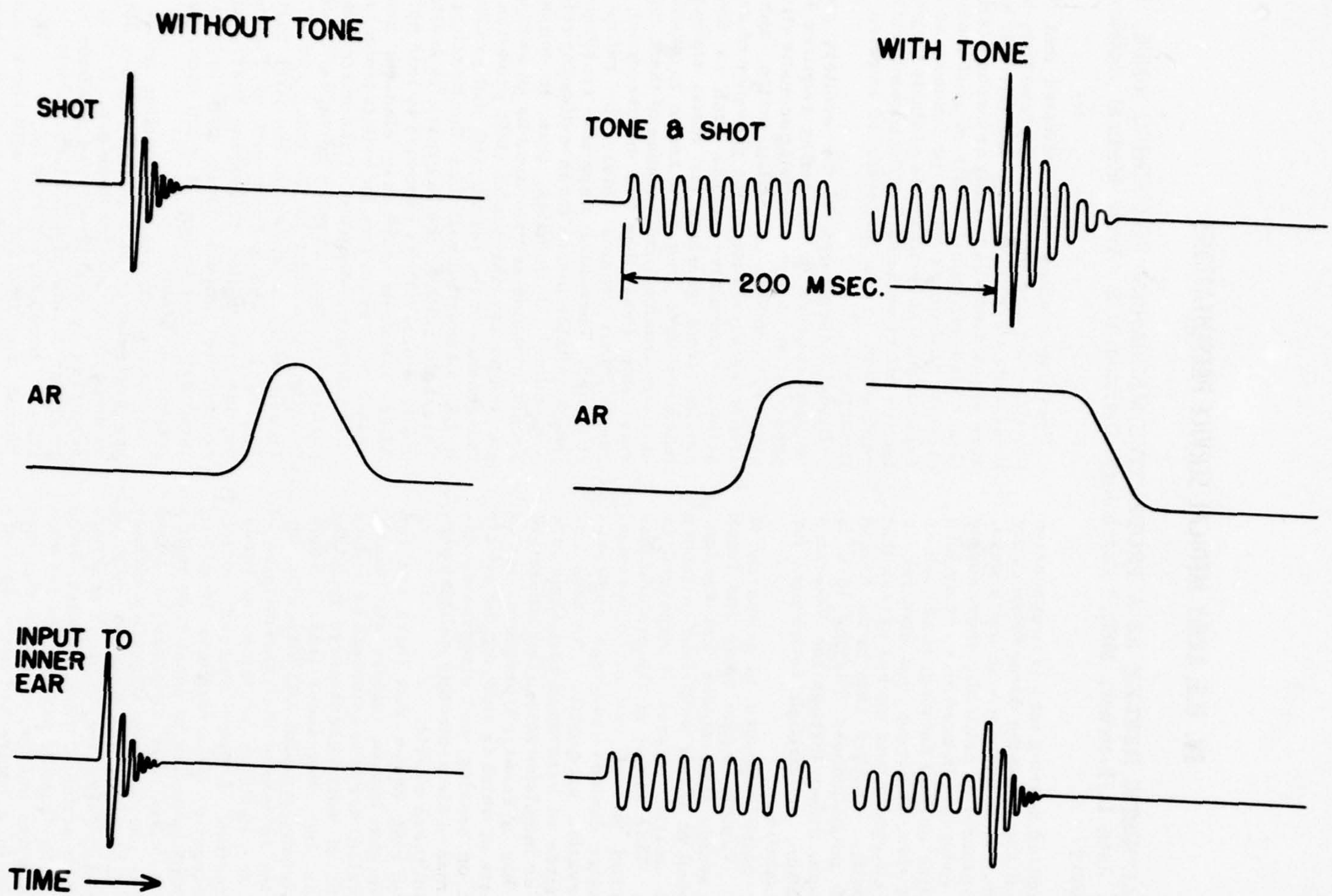

Fig. 1. Schematic representation of two experimental conditions.

a mobile sound laboratory, with the muzzle of the gun pointing out the door. The subject was seated in the operator's position during firing. Immediately to one side of one ear was a 4-inch speaker used to activate the reflex. This speaker, when energized, provided a 1,000-cps activating tone having a sound pressure level of 98 decibels at the ear. Although the sound was heard in both ears, it was less intense at the contralateral ear, the one used for threshold testing.

Calibration of sound intensity of the gunfire was accomplished by determining the average sound pressure with a General Radio sound-level meter and an H. H. Scott peak-reading indicator. The average sound pressure level was 120 decibels and the average peak level was 132 decibels. Because of the extremely rapid rise times of the shots, the above peak level is believed to be conservatively estimated.

Temporal relations between tone and shot were controlled by electronic timers. When the 1,000-cps activating tone was presented, its onset preceded the shot by 200 milliseconds and it persisted until the shot was fired. The period of 200 milliseconds was presumed adequate for full contraction of the reflex.

Thirty-four prospective male subjects were examined by an otologist. Of these, 24 had negative ear, nose, and throat findings and were selected as subjects. All were members of the laboratory and ranged in age from 23 to 37 years. "Normal" hearing was not required for participation in this experiment; however, no attempt was made to make the sample "representative." All subjects participated in at least five training sessions in threshold determination with a Bekesy audiometer. Additional training was given to those subjects whose records were not consistent at the end of the regular training.

The subjects served in two experimental sessions; one in which they were exposed (individually) to the gunfire plus the reflex activating tone, and another session in which they were exposed only to the gunfire. At the beginning of each experimental session the subjects' preexposure audiograms were obtained for frequencies between 250 and 10,000 cps.

They were then seated directly behind the gun. After the speaker was placed in proper position, the subjects were exposed to 100 rounds, fired one round at a time. Usually there occurred a few misfires and double-fires during each session. In order to prevent conditioning of the reflex to a fixed temporal interval, the time between successive rounds was varied randomly between two and six seconds. Elapsed time for firing the 100 rounds was about seven minutes. Upon completion of the firing, the laboratory doors were closed and the subject underwent post-exposure audiometry. In most instances, testing began within 15 seconds of the final shot.

At least 24 hours elapsed between the two experimental sessions, a period found to be adequate for complete recovery of threshold regardless of the experimental conditions. Because of danger of creating permanent threshold shifts, great care was taken to make the noise exposure the absolute minimum for our purposes. Indeed, for some subjects, the firings induced no detectable threshold shift.

Figures 2a and 2b show data selected to represent the range of our results. These data are Bekesy audiogram tracings. The subject listens to a sound and indicates he hears it by pressing a switch. The switch makes the sound softer or attenuates it. When he can no longer hear the sound, he lets up on the switch and the sound gets louder. Thus, the subject traces out his own thresholds. The frequency tested by the machine continually changes. Thus, in some three minutes a sweep frequency audiogram is obtained. The left panels show the pre- and post-exposure audiograms for the ear when not protected by the reflex. Comparable data, taken with the reflex acting, are shown in the right panels. Several observations can be made from these data. First, some individuals (7 of the 24 subjects) showed no threshold shifts even without the reflex (see Subject 1). Therefore, we could not show with our method that they derived benefit from the reflex. Secondly, in virtually every instance in which a threshold shift occurred, the shift following the reflex condition was smaller than it was following the no-reflex exposure, despite the fact that the total acoustic stimulation was greater in the reflex than in the no-reflex condition (see for example, Subjects 2, 3, and 4). Third, total recovery of hearing loss took place between successive days, as can be seen from the agreement between the two-pre-exposure audiograms. This agreement also indicates a relatively high level of reliability obtained with these subjects after they were given the preliminary training. Fourth, absolute protection afforded by the reflex seems to be greatest in the frequency region above 1,000-cps.

Subject 4 was our "best" subject in terms of protection, his protection approximated 50 decibels in the 3,000 to 6,000 cps band. This was not an isolated case; several others obtained nearly as much protection.

The data averaged over all subjects are summarized in Figure 3. This figure shows the amount of threshold shift in decibels occurring under the two experimental conditions. At every point of the graph, the curve for the reflex condition is substantially below that for the no-reflex condition. The

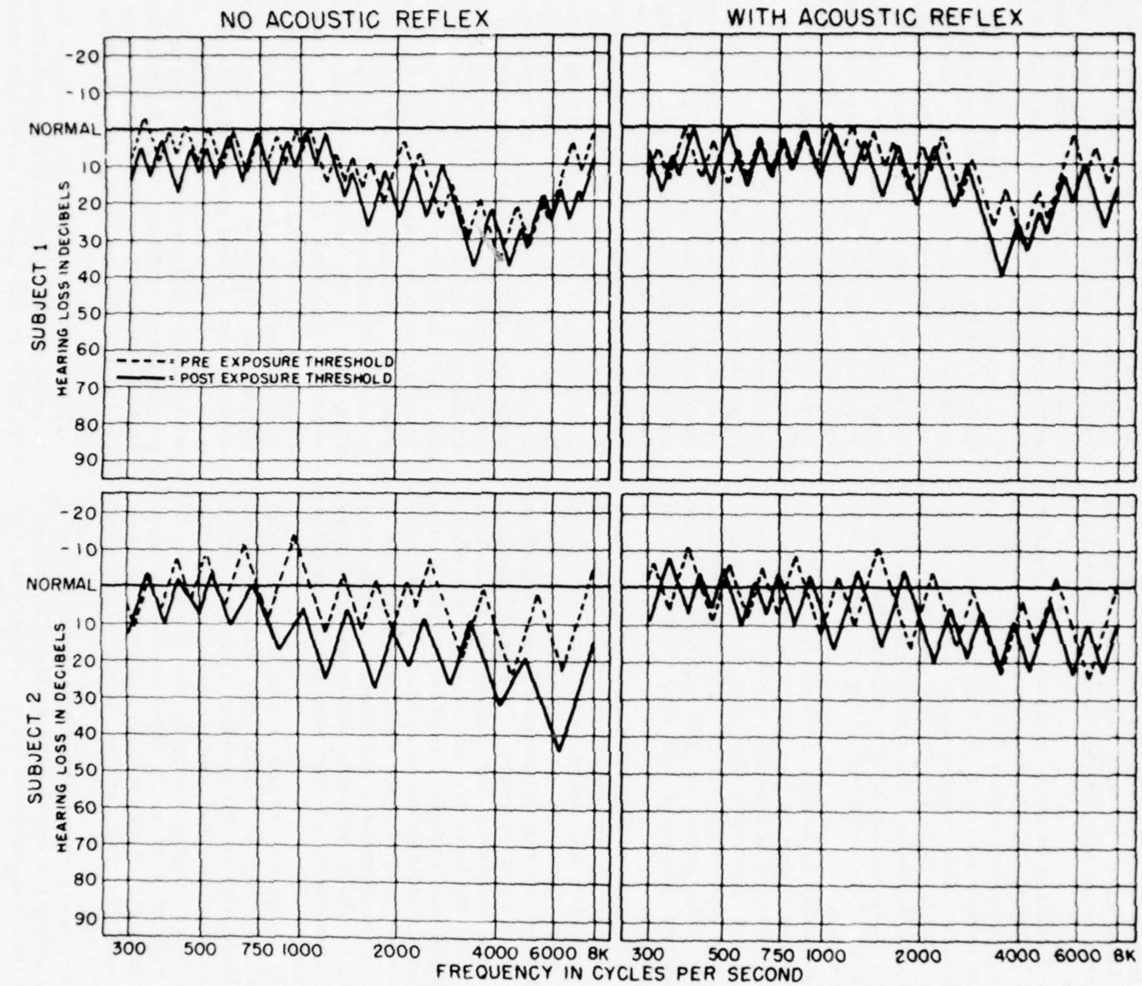

Fig. 2a. Individual audiograms of representative experimental subjects.

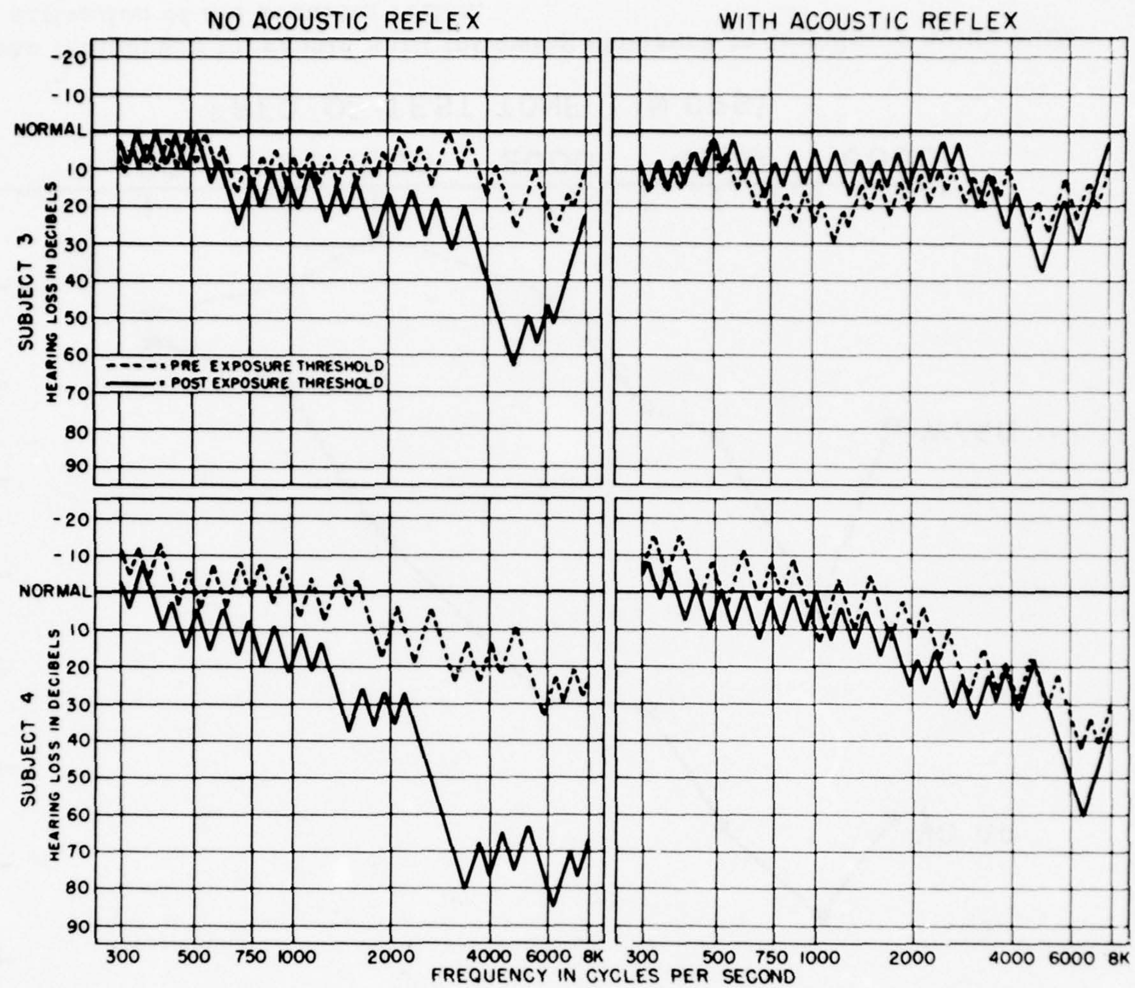

Fig. 2b. Individual audiograms of representative experimental subjects.

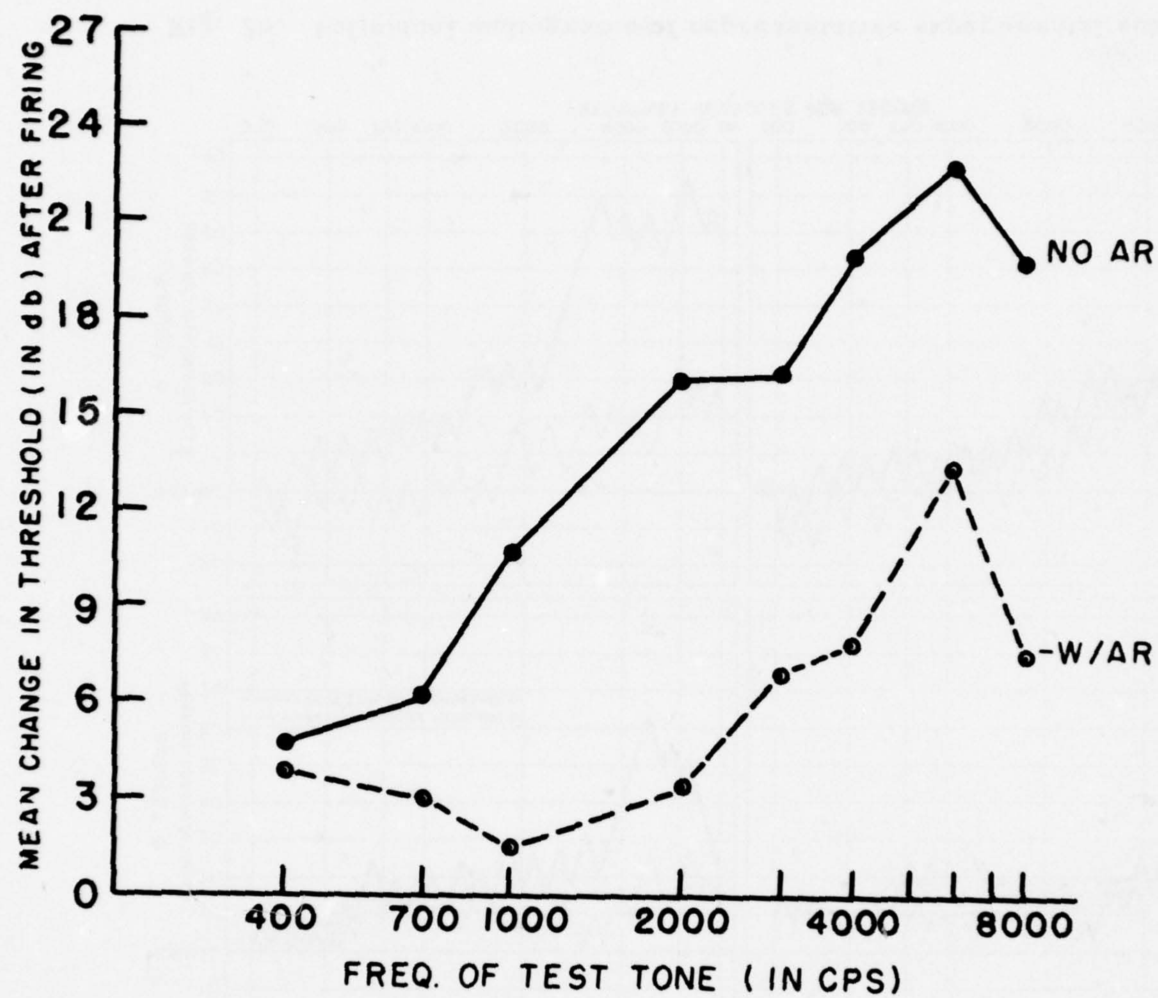

Fig. 3. Mean temporary threshold shift following exposure to impulsive noise with and without activation of the acoustic reflex.

difference between these two curves measures the amount of protection provided by the reflex and averages 10 decibels for frequencies of 1,000 cps or higher. This average would be even higher had we excluded those subjects who showed no threshold shifts under either condition.

The data were subjected to a complex analysis of variance. Analysis of variance is a statistical technique for determining the significant contributions of several factors to the whole body of data. The main effect of conditions, i.e., use of the reflex, was highly significant. Over-all differences between subjects and the differential effectiveness of the reflex for different individuals were both significant. The main effect of differences in frequencies was significant as was the inter-action of frequency and condition. This latter term reflects the fact that the difference between the curves of Figure 3 is least for frequencies below 1,000-cps.

Also of interest are the spontaneous comments of the subjects, upon completion of the experiment, regarding their subjective reactions to the gunfire under the two conditions. Several persons reported that their ears rang during and after the no-reflex session but either did not ring or rang noticeably less after the reflex condition. Every subject who was protected by the reflex remarked that one session (no-reflex condition) was more unpleasant than the other, indicating ready discriminability between the two conditions.

This study shows clearly that under proper conditions the reflex serves to protect the auditory system against temporary acoustic trauma. This view has been espoused by many investigators on indirect evidence. Despite the fact that exposure was held to a minimum, (recall that 7 of the 24 subjects showed no threshold shifts under either condition, and that in every case of temporary threshold shift recovery was complete within 24 hours) the mean protective effect as measured by our method was about 10 decibels for frequencies over 1,000-cps. What is even more significant, protection may be as large as 50 decibels for certain highly sensitive individuals. There is strong reason to believe that had greater exposure been given, more threshold shift would have been obtained, and greater relative protection would have been afforded by the reflex.

The present experiment therefore demonstrates that natural stimulation by acoustic means produces sufficient reflex tension in the intra-aural muscles to attenuate the sounds impinging on the ear.

The similarity in threshold shift for the two exposure conditions at frequencies below 1,000-cps probably should not be interpreted to mean that the reflex is ineffective against high intensity stimulation at low frequencies. On the contrary, data exist which suggest that the maximum attenuation occurs for the lower frequencies, but the threshold for lower frequencies is known to be more resistant to noise induced shifts and to recover from such shifts quickly. What is possible in the present study is that the sound or blast stimulus of a machine gun shot does not contain sufficient energy at lower frequencies to challenge the auditory system to the point of inducing measurable threshold shifts for low frequencies.

Most certainly, the reflex involves the action of the tensor tympani and the stapedius muscles. Whether or not other processes contribute to the over-all protection cannot be determined by the present experiment. The protection afforded for higher test frequencies in this situation in contrast to the attenuation provided for low frequencies by the intra-aural muscles could suggest the operation of additional mechanisms.

In order to determine the protective value of the reflex action relative to that provided by a good commercially available device, a second experiment was run. Subjects were tested with the protection of the reflex and with the protection of the V-51R earplug. The V-51R earplug was chosen because it is one of the best protective devices available and is a medical standard item. Thirteen subjects were tested with pre- and post-exposure audiograms with (1) no protection, (2) with V-51R, and (3) with reflex protection. The measure of protection again was temporary threshold shift.

Results of this investigation showed that there was a significant difference in the protection provided by the reflex and by the plug. Figure 4 plots the threshold shifts resulting from exposure to the firing noise for all three conditions. Over-all mean threshold shift was 19.23 decibels with no protection, 6.27 with the acoustic reflex, and 2.50 with the V-51R. Subjects in this experiment, as in the preceding one, differed significantly among themselves with regard to threshold shifts. Our raw data showed that 5 out of 13 subjects had little or no threshold shift after exposure to the firing noise. The remaining 8 persons had large shifts. Of these with post-exposure threshold shifts, some appeared to be almost completely protected by both the acoustic reflex and the plug, while others were better protected by the acoustic reflex. Figure 5a and 5b contain some of the raw data obtained in this study and give an idea of the individual differences in reaction mentioned above.

Data in Figure 4 show that the acoustic reflex provides more protection up to and including 1000-cps than does the V-51R. Protection at and above 2000-cps was greater for the V-51R. A recent analysis of machine gun firing noise shows that peak energy in the sound lies between 300-1200 cps. Therefore, it is important that ear protection devices attenuate well in this frequency band. The analysis of variance showed a significant frequency X conditions interaction that can best

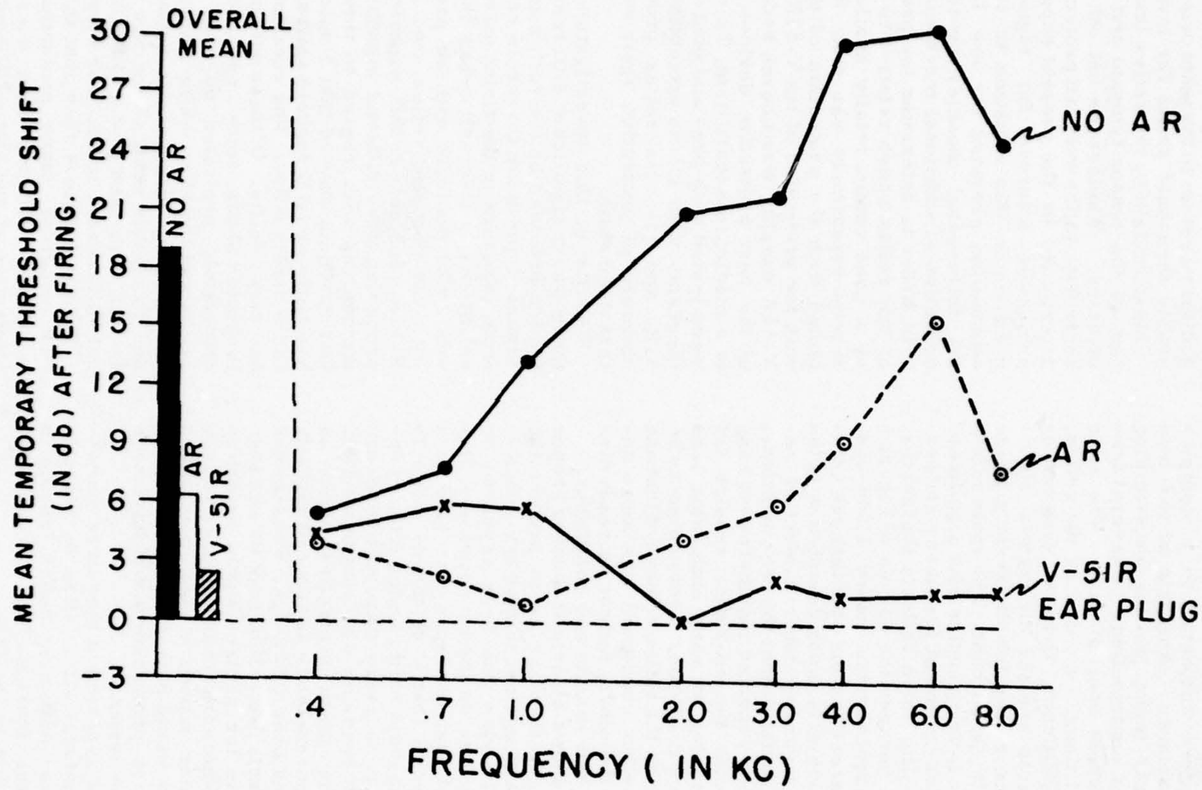

Fig. 4. Mean temporary threshold shift induced by three experimental conditions.

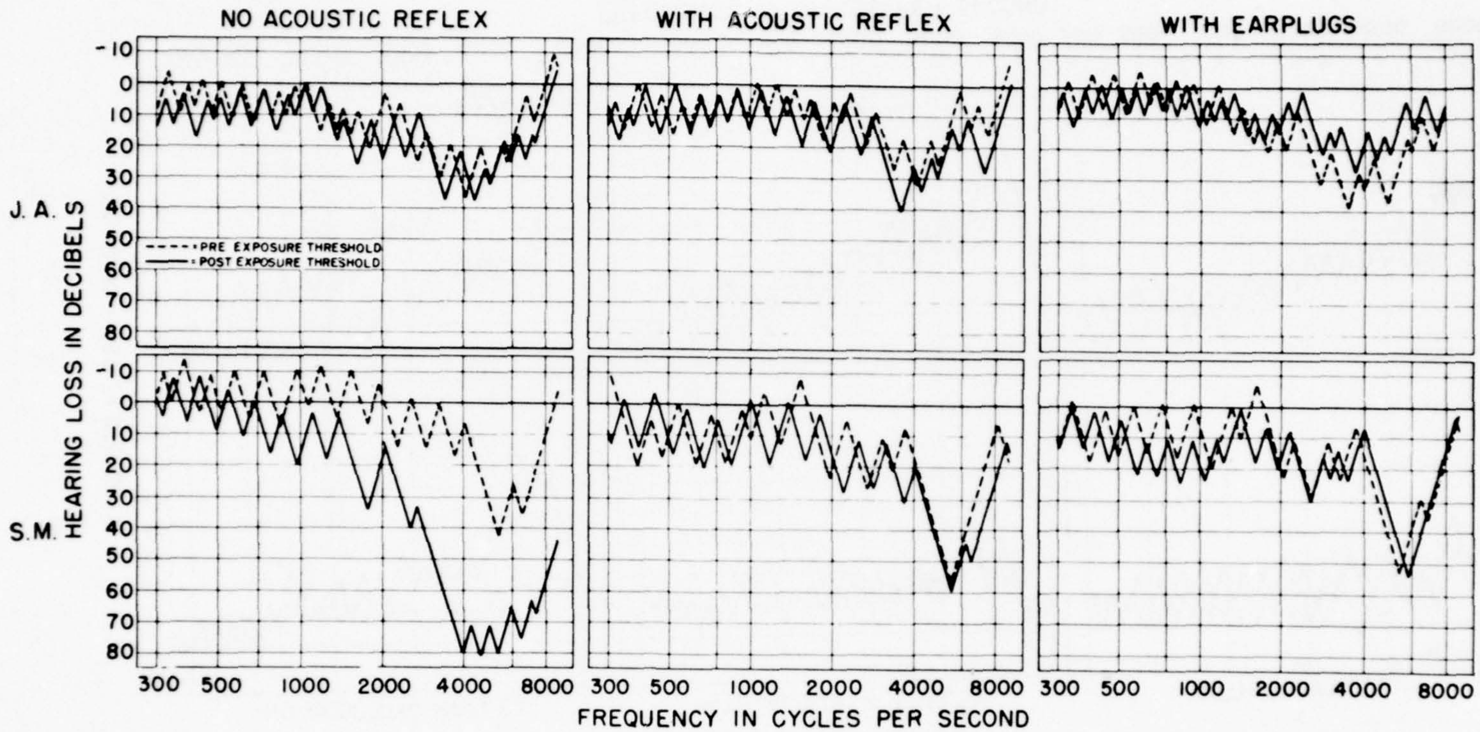

Fig. 5a. Representative audiograms for four subjects under three experimental conditions.

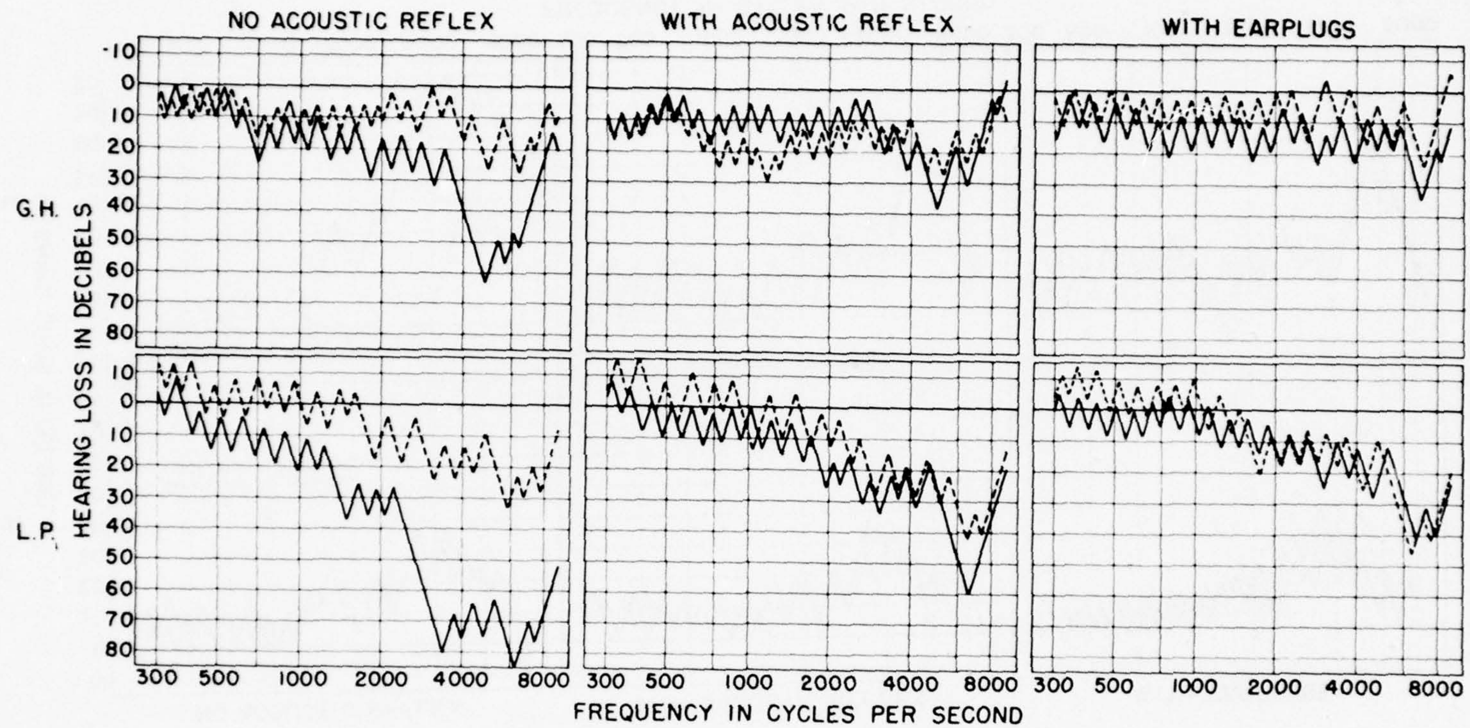

Fig. 5b. Representative audiograms for four subjects under three experimental conditions.

be explained by the selective attenuation results discussed above. Attenuation characteristics of the V-51R (30 decibels or more) lead one to expect good protection for frequencies above 1000-cps. The superior performance of the reflex in the 1000-cps region suggests that it provides in excess of 30 decibels attenuation in this region. We arrive at this figure by reasoning thus: the V-51R attenuates about 30 decibels around 1000-cps and threshold shift is greater with the V-51R than with the reflex, therefore, the reflex probably provides more attenuation than the plug.

Our results indicate that usefulness of the reflex is restricted, probably to situations where energy is high in the low frequency region. Certainly, the V-51R is cheaper and more efficient for sounds 2000-cps and above, provided the situation demanding ear protection is one where insert devices are appropriate. These results suggest that:

1. The reflex be utilized as an ear protective mechanism where low frequency noise of an impulse type predominates.

2. Further research should be done to study possible extensions of the usefulness of the reflex as a protective mechanism. Specifically, steps should be taken to develop and test a reflex ear protective device. Crew members in armored vehicles undergo considerable exposure to firing during training. Organic to armored vehicles is a radio intercom system. Suitability of this system as part of a reflex protective device should be investigated.

The steps recommended in the preceding study were taken. A device to fit into the tank intercom system and activate the reflex to protect the listener from impulse noise was developed. In essence, this device was simply a holding relay and a transistor oscillator. The relay was inserted between the solenoid switch and the firing mechanism and interposed a 200 millisecond delay between the closing of the switch and the firing of the weapon. Coincident with the closing of the switch, the transistor oscillator fed a 1000-cps tone into the tank intercom system. Gain on the oscillator was adjusted so that the 1000-cps tone at the ear of the listener was at approximately 100 decibel sound pressure level.

This device was installed in a tank training turret and 15 subjects fired with and without the reflex activated to determine the effectiveness of the device under operational conditions. The only difference between the two experimental conditions was that in one condition the 1000-cps tone was sounded, in the other, no tone was sounded. In brief, the earphones were left on, and each subject was exposed to 200 rounds of .30 caliber machine gun fire, fired one round at a time with random time between rounds of 1-4 seconds. Because the earphones over the ears provided some protection, 200 rounds exposure was necessary rather than the 100 rounds used in the two previous studies. As in the preceding studies, pre- and post-exposure audiograms were compared to determine temporary threshold shift. Again, we found that the active reflex results in less threshold shift than when the reflex is inactive. A reversal at 4000-cps is probably due to mechanical or acoustic properties of the earphone coupling. Aside from this, the results are comparable to the previous studies.

In summary, these data may have industrial and military significance. Cumulative, progressive, hearing loss following repeated exposure to impulsive noise has often been documented. We have reason to believe that the presence of a reflex-activating tone at a proper interval before each impulsive noise would be a positive beneficial factor in preserving hearing. The acoustic reflex, unlike earplugs, operates only when needed, meaning that oral communication can be resumed immediately following impulsive noise. Another practical benefit is that the reflex is automatic and does not depend upon the discipline of the users; it is a safe assumption that earplugs and other devices are frequently discarded by users.

Further research, aimed at determining the value of the reflex in reducing permanent threshold shift or hearing loss, is now needed.

2. "BIOMEDICAL ASPECTS OF MISSILE TRANSPORT: EFFECTS OF RESTRAINT ON PRIMATES," by Captain William B. Ross, M. C., Psychology Division, U. S. Army Medical Research Laboratory.

The design of animal experiments covering long durations has led numerous investigators into the use of various types of animal restraints. Although the restraints utilized vary in degree of immobilization, positioning, thermal insulation, and environmental isolation, little systematic consideration appears to have been given to the possible effects of restraint alone upon behavior and physiology.

In the course of training rhesus monkeys for use in ballistic missile flights, we became interested in the problem of restraint. Bio-Flight 2B required a rigid restraint for 60-90 hours that would prevent the monkey from interfering with implanted electrodes and lead wires, and would maintain his body and limbs in a fixed predetermined relationship to G forces. Although primates have been kept in specially designed chairs for periods of weeks, these chairs allow for rather free movement of head and limbs. This is in strong contrast to the rigid immobilization required for missile flight.

The "ideal restraint" would have the following features:

1. Provide good heat exchange with the environment.
2. Position the animal in an attitude of rest.
3. Free of pressure points that cause decubitus ulcers.
4. Allow unimpaired peripheral circulation, chiefly in the limbs.
5. Allow unimpaired respiration.
6. Allow some muscular movement so that muscle pumping action can aid venous return and prevent edema.
7. Neither stimulate nor allow struggling which would interfere with recording from body electrodes or increase heat production.
8. Allow for easy collection of urine and feces.
9. Facilitate habituation to restraint.
10. Provoke no chronic stress reaction.

The first eight of these criteria are mostly a matter of good design in "primate engineering." Whether or not the last two are physiologically possible is the unsolved problem. Although a considerable amount of knowledge has accumulated ragarding the manifestations of acute stress, little is known of chronic stress. Acute stress reactions are usually manifested by behavioral changes of excitement, fear, withdrawal, and physiological alterations of increased respiration and heart rate, increased platelets in blood, decreased eosinophiles and lymphocytes, increased blood sugar, and a host of the other well-known physiological accompaniments of what we commonly call fear. The manifestations of chronic stress are not so clear-cut or readily ascertainable at the present time. Faced with the difficulty of even delineating a chronic stress reaction in monkeys, it becomes even more difficult to determine whether habituation is or is not occurring. Despite these limitations in basic approach, some attempts at investigating the effects of restraint have been made.

It has been shown that cats (1), rats (2,3) and guinea pigs (4) show marked decreases in rectal temperatures when restrained and exposed to cold temperatures. This hypothermic response does not occur in the unrestrained animal. Rabbits, when lightly restrained, will develop hypothermia even at normal room temperature. Bartlett, et al. (2) demonstrated that after a week of restraint, rats seemingly adapted to restraint and regained their thermoregulatory ability. He has hypothesized that the emotional stress of restraint triggers off this abnormal cold response, possibly being mediated through the pituitary adrenal-cortical endocrine system. Frankel, et al. (5) demonstrated that position of a rhesus monkey in restraint influences the ability to tolerate heat stresses. Uncomfortable positions were considered to cause either increased struggling resulting in increased body heat production or an emotional response which by vasoconstriction reduced effective heat loss.

Poirier, et. al. (6) utilizing immobilization as an emotional stress in monkeys, found that six hours of restraint caused increase in blood sugar, increased white blood cells, and decreased eosinophile and lymphocyte levels. These changes in blood constituents are believed to be mediated by the hypothalamus of the brain and the pituitary adrenal axis. It should be pointed out here that these seem to be normal responses to the acute stress of restraint. Unfortunately there are no data for restraint longer than six hours. Mason, et al. (7) demonstrated activation of the pituitary-adrenal cortical system in monkeys in the process of just handling them for their first venipuncture, moving them from home cage to experimental cage for the first time and transferring them for the first time to a primate restraining chair. It seems that just a novel environmental change is sufficient stimulus for pituitary-adrenal activation. If this is true, then we cannot expect any restraint, no matter how well designed, to be free of causing these acute stress reactions on the first day of restraint. It is still possible, however, that familiarization and habituation to the restraint could occur so that stress reactions would not be repeated on subsequent insertions into the restraint.

In a preliminary study at the U.S. Army Medical Research Laboratory, Fort Knox, eight rhesus monkeys were anesthetized and immobilized in plaster of paris casts for 72 hour periods. Each animal was placed in a squatting position of rest, then wrapped with orthopedic sheet wadding and plaster-of-paris roller bandage to produce a rigid form-fitting cast from neck to ankles. Animals in casts were suspended in an erect position and hand fed with biscuits, orange slices, and water.

Upon recovery from anesthesia, monkeys that were firmly restrained showed virtually no struggling over the three days. Their electrocardiograms were free of muscle action potentials. Animals with loose casts displayed considerable struggling, and all four of these managed either to work an extremity loose or completely to break their casts. The normally aggressive rhesus monkeys who were well restrained became placid enough to be easily hand fed, although they were alert at all times of observation. The loosely restrained animals remained more aggressive and were hand fed with difficulty.

Rectal temperatures taken hourly showed ranges on all eight animals of 96-98°F over the first 36 hours and 100-101°F over the last 36 hours. These initial hypothermic temperatures are in line with studies cited earlier on restraint in smaller animals.

Fasting blood glucose determinations were done through the day hours. Although large fluctuations were observed in each animal, mean daily values were 151 mg%, 123 mg%, and 112 mg%. This decline over the three days probably represents a decrease from the abnormally high values of the initial acute stress reaction down to the more normal basal levels.

Two complications were encountered in this restraint procedure. Three animals developed moderate to severe pressure sores, probably as a result of uneveness in the applied wrappings. Most animals developed a dependent edema of the feet within 48 hours of restraint. The edema cleared almost completely within 24 hours after removal of the casts.

Immediately after removal from restraint, monkeys regained their usual bellicose behavior. Normal cage life was resumed in the colony, without exception or sequelae.

In a later series of experiments, four monkeys were cast in plaster with the intention of maintaining them for five days in restraint. Two animals died, one at 12-16 hours, and the other at 30-36 hours. The first was found at autopsy to have a consolidated lobar pneumonia and the other a generalized septicemia. Although these pathological processes could not have been due to the restraint procedure, the possibility exists that the stress of restraint added to subclinical disease states may have weakened normal defense mechanisms sufficiently to cause death.

The limited observations in this preliminary study precludes any generalizations or conclusions beyond the statement that rhesus monkeys can survive long periods of continuous rigid restraint. That behavioral and physiological alterations do occur during immobilization seems evident, but a fuller description of alterations, their duration and intensity, remains for completion of studies in progress.

For our present study we have devised a restraint consisting of a polyurethane foam couch and an acrylic resin top mold. To make the top mold, an anesthetized monkey is wrapped completely in three layers of orthopedic sheet wadding, then covered with a layer of aluminum foil. Acrylic resin is then spatulated directly onto the animal and allowed to set for 15 minutes. A custom molded restraint can be made in this manner in about an hour.

Monkeys are first being placed for five continuous days in a standard primate behavior chair which restrains the animal by yokes on the neck and waist. After five days of non-performance in the chair, shock avoidance conditioning is started. Electric shocks are administered to the animal through the chair seat until the animal learns to depress a lever repeatedly to avoid the shock. When the animal has reached a stable level of performance in lever pressing, he is transferred to the acrylic contour mold for five continuous days where lever pressing performance is continued. One week later the animal is returned to the contour mold for another five day session.

Throughout these phases of restraint the animals are followed with serial hematological determinations, biochemical studies, behavioral observations, rectal temperature, heart rates, electromyograms, and shock avoidance behavior scores. This protocol is expected to shed light on the following problems: What are the behavioral and physiological effects of immobilization? Can a monkey be habituated to restraint? Are restraint effects self-limited over time?

It is theorized that in a well matched restraint the alterations will be mainly those of an acute stress reaction, that these effects will be self-limiting, and that animals can be habituated to immobilization. Whether or not the particular restraint used in this study will produce this ideal remains to be seen.

Since in ballistic missile transport experiments involving monkeys it is necessary to differentiate acute stress responses to restraint from those of flight itself, it becomes important to follow one of two procedures: (1) either immobilize the animal in the missile for several days prior to lift-off so that the response to restraint has subsided, or (2) habituate the animal to the situation by repeated trials in the restraint couch so that the stress response does not occur when the animal is restrained on the day of lift-off. Furthermore, as pointed our earlier, a restraint period prior to lift-off might serve to eliminate animals with subclinical disease processes. An animal that could not survive the stress of restraint probably would not fare well with the stress of ballistic missile flight.

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V. CORPS OF ENGINEERS AND TRANSPORTATION CORPS PRESENTATIONS

1. "HUMAN ENGINEERING IN THE DESIGN OF MILITARY CONSTRUCTION AND INDUSTRIAL EQUIPMENT" by A. J. Rutherford, U.S. Army Engineer Research and Development Laboratories.

The purpose of my talk is to discuss one aspect of our current methods for obtaining good man-machine relationship in design of an important category of our military equipment, and to suggest ways by which these methods may be made more effective.

Before proceeding further, allow me to acknowledge the splendid contributions now being made to the advancement of human engineering, both by organizing it as formal program within the framework of an overall effort, and by informal application of its principles as an integral part of each independent project. The Corps of Engineers has generally followed the latter method in executing its program for making available the construction power by which the deployment of fire power is made possible.

One need not spend time setting forth the value of a human engineering approach to equipment design, since its merit has already been well established I shall, however, repeat the words of the Hon. William H. Martin, Director of Research, Department of the Army, when he addressed a human engineering conference in 1955. He said, "Human Engineering is a practice well worthwhile, particularly in our military equipment; it requires a quantitative approach to get best results; and, to realize fully the desired benefits, it is necessary to give users instructions and training".

These words of Dr. Martin are particularly meaningful because they emphasize three important points:

1. Human engineering must reflect its effect in the finished product which reaches the user's hands
2. Human engineering must be quantified to produce best results, and
3. The user must be made aware of the human engineering attributes of the product he is to use.

If we examine the research and development process, we see an everchanging, dynamic exercise wherein ideas are converted to postulates which, upon verification, become theories or principles. Using these principles we create concepts for development, conduct development feasibility studies, make experimental designs, and fabricate experimental models. From these models we develop production prototypes. At this point we know -- or should know -- enough about the product and its intended use to be positive and accurate in preparing the description of its design for production.

The military expression for this description of the results of research and development is the end-item or material specification -- a document designed to communicate to persons conversant with the art of production a clear and concise description of what they are to produce.

Now where does human engineering fit into this spectrum? I think we can safely say, "It fits in from the beginning to the end". For instance, ideas for research and development generally spring from the motive to satisfy human need. This signifies need for recognition and comprehension of the physiological and psychological attributes of the human being, in order that he may be categorically described and his characteristics correlated to material elements. Likewise, each material needs critical examination with respect to its affect on the human. When we introduce the variability of environments, such as exist on this earth and in outer space, we are faced with a complex of an ever-changing spirit-energy-material relationship that will perplex and challenge the human-engineer for centuries to come.

It is reassuring to know that tremendous strides have been made, particularly in the past few decades, toward establishing data that quantitatively set forth the factors to be considered in machine design. Handbooks are available that set forth quite specifically and accurately the properties of different materials. More recently, handbooks on human engineering have become available that make valuable contributions to our knowledge of human limitations and capabilities. In the medical psychological field, much information is being assembled and organized to provide help in quantitatively dealing with the cultural and emotional factors that control human behavior and response.

It is my privilege to work in the field of evaluation engineering; that is, that phase of research and development that deals with the determination of whether or not an item, intended for military use, reflects significant improvement over previous states-of-the-art, and, if so, to what degree and in what

respect. Naturally this leads to a never-ending search for the ways and means of measurement required to establish standards on which judgment may be based.

Unfortunately, in the area of human engineering, good standards are nonexistent and the available human factor data are not used to advantage in product specifications. Moreover, when attempts are made to stipulate desired man-machine relationships, the descriptions are so ambiguous and generalized as to void their significance in the enforcement of provisions on the designer or producer. For examples, as a preliminary to preparation of this paper, I studied two military specifications that described end-item vehicles, on which a man was required to ride and control for effective performance. These vehicles were designed for adaptation to a wide variety of environmental and terrain conditions. I studied the specification with close attention to the interactions between the man and the machine, particularly as to conditions that affect performance. My observations with respect to certain factors are presented in Table I.

As you see, there is precious little attention given to the human being in either of these two performance type specifications. I dare say that they are typical of 90% of the end-item specifications of issue in effect at this time.

Now what can we do about the situation? First, let us examine the policy. Generally speaking, the policy for Government procurement demands that what we buy must be based on the job to be done; we must not ask for more, or less, than that required to meet the needs. Products must be purchased at the lowest price and without discrimination against anyone who is legally authorized to do business and able to meet the demand, and who conforms to acceptable business ethics and labor practices.

This policy creates a fundamental need for precise ways and means of defining, quantitatively, the needs to be fulfilled. In other words, we must specify the way of measuring, and the quantity to be provided in accordance with the measurement. Instead of a statement like "Controls shall be within easy reach of the operator while seated", let us state, "Hand operated controls shall be located within a frontal arc of 120 degrees from the operator's seat and not greater than 40 inches nor less than 25 inches from the center of the seat. Controls shall be not greater than 33 inches nor less than 4 inches above the level of the operator's seat".

A significant step forward was recently made when the Department of Defense directed the Corps of Engineers to establish a Military Standard on Test Methods for Construction and Industrial Machinery. The draft format of this standard makes provision for test methods to deal with the functions of mobility, job performance, reliability, transportability, maintainability, safety and operability. In each of these functional areas the human element plays an important part. However, "operability" is defined as "the human engineering aspects of equipment design or behavior which renders it adaptable to the capabilities and limitations of the operator". Under this functional area it is proposed to code precise methods for determining whether the physiological and psychological attributes of the human norm are violated by machine design.

In summary I shall again refer to the points made by Dr. Martin and add that: (1) To get good human engineering we must demand it in the finished product, and the best way to do this is to require it in the material or end-item specification. (2) Human engineering must be quantified to get results -- this means that there must be standards for measurement. (3) Users must be made aware of human engineering by instruction and training, in order that we gain the "feed back" information necessary to determine our position and set the course for further progress.

The way to get immediate and practical effect from human engineering is to demand it as a requisite for the purchase of all products. To do this, a program for determining how to state the human engineering requirements in procurement specifications, and to develop the standards for determining that requirements have been met, is a compelling necessity.

"THE ROLE OF THE TRANSPORTATION CORPS IN MILITARY FIRE POWER" by Dr. John Wendell Bailey, U. S. Army Transportation Research and Engineering Command.

To be successful military operations must have adequate logistical support. The Transportation Corps' chief duty is to provide this support. We physically move men and material to any required spot on the globe in time to accomplish the assigned mission. In Civil War parlance, we try to "get there fastest with the mostest". Of course, this will be done with the assistance and cooperation of the other branches of the services in communications, techniques and equipment that will speed the acquisition of information and the decision-making processes. Increased mobility requires an overall reduction in logistical tonnages; equipment that is more rugged, yet easier to maintain and operate. In short, it will require much human factors engineering, all along the line, to make and maintain an efficient fighting force, on land, on water, or in the air.

Table I - Remarks on Human Factors Noted Respecting Two Selected Military Characteristics Documents

Stated Requirement in Specification MIL-T-52045 (CE) Tractor, Wheeled, Industrial	Stated Requirement in Specification MIL-C-10466B Crane-Shovel, Truck Mounted	Remarks
MAN'S RESISTANCE TO TEMPERATURE		
3.3.1 Thermal conductivity (insulating material) shall not be greater than 0.7 BTU per hr for mastic type and 0.25 BTU per hr for sheet and blanket types. 3.32.1 Cab shall be provided with heating system with manual and automatic controls to insure crew comfort. 3.32.11 Personnel cab shall be completely insulated and weather stripped to protect against blowing snow and air drafts. 3.32.11.1 Cab floor shall be insulated with a fitted felt floor mat not less than 1/4-in thick with neoprene coating. 3.32.11.2 Top and sides of operator's compartment shall be insulated with a mastic type insulation and a rubber sheet insulation. 3.32.11.3 Weather stripping shall be used to seal doors and covers. 3.32.11.4 All levers and controls within cab shall be equipped with low temperature boots to keep out air and weather elements. 3.32.11.5 Provision shall be made for securing all doors in open position to provide full ventilation. 3.32.11.9 Cab shall be equipped with two personnel heaters. Each without aid of other shall be capable of maintaining an average temperature in operator's compartment of at least 45F with an outside ambient temperature of -65F and a wind velocity of at least 5 mph.	3.10.6.1 The crane cab and carrier cab on non-winterized units shall contain a heater conforming to specification MIL-H-3199. 3.17.1 Two separate winterization systems of crane and carrier shall provide insulated enclosures and heaters to ensure crew comfort. 3.17.2 Personnel heating systems shall be capable of obtaining and maintaining a cab temperature of 35F to 45F at an ambient temperature of -65F and wind velocity of 5 mph. 3.17.14 The sheet metal carrier cab shall be completely insulated and weather stripped to protect against entrance of blowing snow and air drafts. 3.17.15 Minimum average temperature in operator's compartments shall be maintainable between 35F and 55F, or specified low temperature conditions. 3.17.16 Floor of operator's compartments shall be insulated with fitted floor mat. Top and sides shall be insulated with mastic type insulation. All doors and openings shall have a weather stripping seal to prevent entrance of air or blowing snow. 3.17.17 Provision shall be made for securing all doors in the open position to provide for full ventilation in the operator compartments during seasons of high ambient temperature. 3.17.18 All levers and controls in floor, dash, etc., shall be equipped with boots or equivalent to keep out air and weather elements to conserve heat and eliminate drafts. 3.17.19 The type of weather stripping and methods of securing it shall prevent entrance of blowing snow.	Although numerous design requirements are specified, no quantitative values are given to insure protection of the human from the temperature extremes that are known to affect efficiency and impair health. Specific values should be applied.
MAN'S RESISTANCE TO MECHANICAL AND ELECTRICAL SHOCK		
3.21.1 Tractor shall be equipped with two adjustable spring-supported padded seats and back rests.	3.10.6 An adjustable and comfortable operator's seat shall be provided. 3.11.5 Front axle springs shall have a minimum practicable rate with a frequency of not greater than 150 cpm. Shock absorbers shall be used to effectively lower the amplitude of the secondary spring action. 3.11.8 Tire pressures shall be as shown in Table VI, under all operating conditions (70 - 95 psi, depending on size of truck, loading rating and size of tire). 3.11.13 Operator's seat shall be independently suspended on torsion springs and fully adjustable, horizontally and vertically. Cushions and back shall be padded with foam rubber.	Quantitative requirement for mechanical shock dampening should be specified to protect the human from excessive fatigue and injury. Where electrical potential exceeds 40 volts, quantitative values for dielectric properties of conduits and other insulators should be specified.
MAN'S RESISTANCE TO TOXIC MATERIALS		
3.5.8 Exhaust muffler shall be provided with flame or spark arrester for engine exhaust. 3.32.4 Contaminated hot air shall not be exhausted near heater fresh air intakes. 3.32.11.5 All cab doors shall be secured in open position to provide for full ventilation.	3.17.9 Heater exhaust gas shall not be directed within area of fresh air intakes. 3.17.17 All cab doors shall be secured in open position to provide for full ventilation.	Specific quantitative values should be stated for protection of the operator or other personnel from injurious effects of toxic materials, such as exhaust gases.
MENTAL ATTITUDE TO INSECURITY		
3.5.2 Engine shall be designed and constructed to operate satisfactorily for extended periods of time on 35 per cent side slopes and 60 per cent longitudinal slopes or any combination thereof. 3.12 Tractor with attachments shall be capable of negotiating and sustaining operation on 35 per cent side slopes and 60 per cent longitudinal slopes without any wheels losing contact with the ground.	3.8 The overall height of crane-shovel shall not exceed 10 ft 8 in; the overall width, 12 ft. 3.9.3 Minimum computed per cent grade ability shall be not less than that shown in Table IV (1/2 to 48 per cent, depending on truck crane size and gear).	Although design requirements indicate need for consideration of the stability of the equipment, no provision is made for the psychological affect of machine behavior on the operator.
MAN'S RESISTANCE TO RADIATION		
No requirement stated.	No requirement stated.	Forecast of the potential for radiation exposure or "fall-out" may dictate the quantitative prescribing of levels of radiation protection required for the operator.

Stated Requirement in Specification MIL-T-52045 (CE) Tractor, Wheeled, Industrial	Stated Requirement in Specification MIL-C-10466B Crane-Shovel, Truck Mounted	Remarks
MAN'S NEED TO SEE		
3.1 a. Tractor shall be equipped with safety glass windshield extending laterally across operator's compartment. b. Provision shall be made for defrosting 80% of area of the windshield. c. Provide electric windshield wipers on front and rear windows. 3.21.2 Instruments shall be located so the operator may conveniently read them from the driving position. 3.28.1.1 Lights shall provide acceptable road illumination.	3.10.6 a. Superstructure cab shall have sufficient windows and glazed doors to permit 180 degree vision. b. Seat shall be located to provide unobstructed visibility of work. 3.10.7.3.3 Two 21 candlepower lights located at the top shall provide general illumination inside the cab. 3.10.7.4 A suitable instrument light shall be provided to illuminate each instrument panel. 3.10.8 Boom angle indicator shall be located near and visible from the operator's seat. 3.10.9 Controls shall not cause any obstruction to the operator's view of the work. 3.17.8 Defrosters shall maintain clear vision through 75% of each window area. 3.17.21 Windshield wipers shall provide optimum view of operations during adverse weather conditions. 3.28 Gross vehicle weight shall be stenciled on each side so as to be readily discernible to personnel handling the equipment.	Requirements should specifically state the area of vision needed for the operator to see his work, to drive and to watch for the approach of objects or personnel that may interfere with performance. Standards are needed for measuring horizontal, vertical or spherical parameters of vision. Lighting requirements should quantitatively specify the intensity of light required with respect to location and need for visibility. Gauges, dials and similar read-type instruments should be specifically sized for distance from the viewer and located objectively with respect to the viewer and frequency of referral.
MAN'S RESISTANCE TO NOISE		
No specific requirement.	3.17.19 Weather stripping shall reduce vibration noise to a minimum.	Noise levels should be quantitatively specified to a magnitude that does not interfere with communication, reduce efficiency or constitute hazard.
MAN'S PHYSICAL STRENGTH		
3.21.3 Controls shall be operable with minimum effort.	3.10.5.1 Clutch shall require normal effort to engage. 3.10.9 Superstructure controls shall be easy to operate with operator seated.	Requirements should quantitatively state ranges of pedal and lever force with respect to location and frequency of application. Torque for operation of hand knobs and switches should be quantitatively stated. Weight and location of components to be manually handled should be specifically controlled.
MAN'S BODY SIZE		
3.21.1 Seat shall be sufficiently wide to seat a man comfortably. 3.21.3 All controls for tractor and attachments shall be operable from the operator's seat and be within easy reach of operator in normal position for operations. 3.22 Universal rifle case shall be mounted on equipment in location readily accessible to operator. 3.23.3 Winch control levers shall be located so as to be readily manipulated by the operator seated on the tractor. 3.29 Fire extinguisher shall be mounted so as to be readily accessible. 3.32.1 (e) Winterization system shall permit accessibility to controls, adjustable devices and valves, together with simplification of maintenance for operators handicapped by bulky clothing. 3.32.6 Battery box cover shall be provided with handles to permit removal with mittened hands. 3.32.6.2 Battery cover shall have quick opening latches and accessible handles sufficiently large to facilitate operation by heavily-mittened hands. 3.32.8 Engine housing latches and handles shall be proportioned to facilitate grasping and manipulating with heavily-mittened hands. 3.32.11 Cab shall present minimum restriction to functions of maintenance and provide space to assure easy entrance, operation and exit for operator wearing full arctic clothing and arctic mittens. Door handles, levers and other devices shall be easily operated by heavily-mittened hands. 3.32.11.7 Cab escape hatch shall be of sufficient size to allow emergency exit of a fully arctic-clothed operator. 3.33 Unit design shall provide ready access to components for maintenance personnel wearing mittens, bulky clothing and foot gear.	3.10.4.1 Swing lock and brake controls shall be located within easy reach of operator while seated. 3.10.5.1 Clutch shall be controlled from operator's seat. The main clutch shall be located so as to be easily accessible for adjustment and repair. 3.10.6 Operator's seat shall be located within easy reach of control levels and pedals. 3.10.9 Levers and pedals shall be conveniently located and arranged, and designed to facilitate easy access and operation by operator when seated. 3.11.8 Spare tire, wheel, and tire carrier shall be mounted in an accessible location. 3.11.11 Carrier controls shall be within easy reach of operator when seated. 3.15.2.4 Governor shall be controlled by lever within easy reach of operator when seated in cab. 3.15.2.5 Manual engine controls and instruments shall be mounted on instrument panel to be easily viewed and operated by operator when seated. 3.17.1 (d) Winterization shall provide accessibility to controls adjustable devices and valves, together with simplification of maintenance for operators handicapped by bulky arctic clothing - parka, mittens & boots. 3.17.8 Cab heater control panel or box shall be mounted on or adjacent to instrument panel for easy accessibility by operator. 3.17.12.4 Battery cover shall be provided with quick-opening latches and accessible handles large enough to facilitate operation by heavily-mittened hands. 3.17.13 On crane cab, provide opening between operator and drum compartment large enough for an operator to reach drum and cable clutch adjustments. Repairs shall be easily accessible, either directly or by easy removal of panels. 3.21 Fire extinguisher shall be mounted so as to be accessible to operator. 3.32 Universal rifle case shall be mounted in location readily accessible to operator.	Requirements should state quantitative values for arrangement and configuration of cockpit and operator controls. Anthropometric data currently available should be the basis for establishing quantitative requirements for operator accommodation.

It is the intent of this presentation to give a thumbnail sketch of the Transportation Corps and to outline briefly, and in part only, what has been done in this area; and, where possible, to highlight some of the most urgent problems that still confront us.

The U.S. Army Transportation Corps was first organized as a temporary branch of service on 31 July 1942. It was conceived as a world-wide transportation network dedicated to the service of moving men and supplies. The Corps was permanently established on 28 June 1950. Only recently, 31 July 1959, we celebrated our 17th anniversary. During this short but eventful life our responsibilities have expanded steadily until today our activities are global in nature, involving transportation operations, east and west around the world and north and south from the antarctic to the arctic.

With these widespread commitments, we are constantly striving to place emphasis where it is most needed. At present our most critical need is to find means of bridging the gap which has developed between mobility and fire power. This gap has resulted primarily from spectacular technological breakthroughs which have been made in missilery and in nuclear weapons, with attendent requirements for dispersion.

The Transportation Corps is often spoken of as the "Core of Mobility", with each of its diverse activities adding a spoke to the central hub, mobility for the Army. As a part of the program to achieve this mobility and thus close the gap with fire power, we have instituted numerous aero-mechanical research projects.

Our goal is to get the Army out of the mud. To do this, our serial vehicles must fly low and slow, moving material and weapons about the battlefield, as the exigencies of combat dictate. Several of our more promising test vehicles have flown this past year, and we have hopes for future success in this field.

In the combat area our role has been increased materially. Of the 120 company-sized TC units in the type field Army, some 90 are liable for combat roles. Organizationally, our units are placed as far forward as the R.O.C.I.D. Division, whose TC battalions provide frontline mobility for the Infantry, with trucks and personnel carriers.

As our combat role increases, we are obliged to increase the front line effectiveness of the Transportation Corps soldiers. We must insure that we understand every item in the training program, by staying abreast of the latest doctrine and techniques.

Turning from our combat role to our support roles, we have also made important strides in the field of logistics.

Our containerization program, already the most extensive in the world, includes not only a fleet of 51,000 Army-Air Force Conex Containers (boxes), but now embraces trailer-van service, from CONUS depots to U.S. depots in Europe. This service utilizes a fleet of trailer-vans in conjunction with two MSTS Roll-on/Roll-off ships, the Comet and the Tourus. We can deliver critical cargo, depot to depot, in an average of 19 days.

At a previous meeting of this group I presented the Navy's Roll-on and Roll-off ship, the Comet. This ship is a more or less glorified edition of a Staten Island Ferry, which can carry many tons of vehicles in holds which are interconnected by ramps and passages to allow the entire load to roll off the ship via a stern ramp or side ports under its own power. This provides a discharge rate far exceeding that obtainable with conventional ships and conventional cargo gear. However, all of this potential ability is unuseable if, when faced with the objective of landing cargo on an undeveloped beach, no means are available for bridging the water gap which remains after the ship has moved in as far as its 22-foot draft will allow. To meet this situation, TRECOM designed a ship which can be held in contact with the Comet and receive the BDL's ship's ramp upon her deck for transfer of vehicles.

This ship is called the U.S. Army Beach Discharge Lighter (BDL IX) and named the Lieutenant Colonel John U. D. Page. 1/ The transfer operation, or marriage of the ships, as demonstrated recently in tests in the Chesapeake Bay, Virginia, was as follows:

The ships are held together, stern to stern, contact by steel cables kept at a predetermined tension by remotely controlled rams on the after deck of the "Page". The stern of the "Page" has a large steel fender which presses against vertical rubber guards on the flat stern of the "Comet". A section of the bulwark across the stern of the "Page" is removed to allow the stern ramp of the "Comet" to rest on the deck of the "Page". Hinged sections at the tip of the ramp compensate for a considerable roll of one ship with respect to the other and a certain amount of sliding between the hulls as the ships rise and fall.

The vessel has a length of 338 feet and a beam of 65 feet. It is equipped with radar, Loran, radio direction finder, and ship to shore telephone besides normal radio equipment, gyro-compass, and fathometer. With a full load of supplies and fuel for a 4,800 mile cruising radius, the ship's displacement is 4,126 tons, but at the normal landing draft

1/ Lt Col Page was a winner of the Congressional Medal of Honor in the Korean conflict, and a member of the X Corps Artillery; was mortally wounded 10 December 1950 while attached to the 52nd Transportation Truck Battalion.

of 4 feet forward and 10 feet aft, the displacement is 2,340 tons.

Approximately 17,800 square feet of open deck space is available for parking up to 600 tons of vehicles, or stowing general cargo. This area is broken only by a narrow deckhouse amidship. Below the main deck are accommodations for 30 men and a waiting room for 200 transient vehicle drivers. Two 1100 horsepower Fairbanks-Morse opposed-piston diesel engines drive the vessel at slightly over 10 knots per hour.

While the Army Transportation Corps developed the project designed to service MSTS and maritime administration (Merchant Marine) ships, and the Army provided the funds, the contract was issued by the Navy, and the Navy supervised the building under the Single Department procurement responsibility program of the Department Defense.

Combining a high degree of maneuverability and self sufficiency with ease of loading and discharge, the Beach Discharge Lighter adds a new flexibility to the Army's over-the-beach operations.

Especially adept in navigating shallow rivers and coastal waters, as well as being self-deliverable overseas, the "Pag-" promises to be one of our most valuable tools in rushing combat vehicles and supplies over undeveloped beachheads in wartime.

Some optimistic transportation personnel predict about one-fourth of all resupply cargo is expected to be of the roll-on/roll-off type; that is, wheeled or tracked vehicles and other equipment.

The 60-ton capacity BARC and the 5- and 15-ton capacity LARC amphibian developments round out the family of marine craft designed to transport the various types of resupply cargo from ship to shore where fixed port facilities are not available.

Our new amphibian, the LARC, has been successfully demonstrated and is now being tested under rather strenuous conditions at Indio, California. Both LARCs are being built of aluminum, with emphasis on their waterborne characteristics, since they are expected to swim about 75% of the time.

In time of war, the railroads are the backbone of land transport both in the CONUS and overseas. Fuel, rations, ammunition and personnel are transported from port areas to forward railheads in impressive tonnages. A standard military supply train generally consists of about 35 freight cars, each of forty tons capacity, an engine and crew of approximately five men. To move the same tonnage overland or on a highway would require 560 two and one-half ton trucks and a whole battalion of drivers. Military train crews frequently operate for 48 hours and longer without relief. It is the desire of the Rail Division to get some type of caboose car designed for the use of these train crews. Tired men often become careless, and careless men do not live to a ripe old age on the railroad. There is a lot of room for improvement in safety of design in military railway equipment. Austerity is one of the basic design principles and an admirable one, but it should be thoroughly coordinated with human factors engineering requirements in initial phases so that ease and safety of mechanical operation are at a maximum.

One other phase of equipment design reform is the requirement for simplification of operating controls in diesel locomotives and cranes. The use of indigenous personnel is a worthwhile achievement, but it is easy to envisage the dismay a diesel locomotive control panel could occasion with a semi-trained native, and the subsequent damage to expensive machinery by mishandling.

Railway equipment is designed primarily for human comfort and security, and includes the Ambulance Unit Car for domestic service, and the wide and narrow gage ambulance trains for foreign service. All of these cars have been designed with the comfort of the wounded and the convenience of the medical personnel as major objectives. The domestic ambulance car has the capacity for 27 patients, 6 orderlies, 1 nurse and 1 doctor. It has its own source of power, is air conditioned and contains full kitchen facilities. In time of disaster, these cars could be moved to the closest railway siding and become mobile integral hospitals. The Army has designed and built sixty-three of these cars which are stored at various parts of the CONUS.

The foreign service Ambulance Train consists of ward cars, personnel cars and kitchen-dining cars. The ward car is self-sufficient with air conditioning, diesel-generator set, heating, and accommodation for 30 patients. The personnel car contains storage facilities and accommodation for 15 EM, 4 doctors and 2 nurses. The kitchen-dining car has the seating capacity for 24 persons and the food storage and cooking capacity for 150 persons. Each car is equipped with a 25 KW diesel-generator set for lights, heating and ventilating. A train may be made up of any number of each of the three types of car. The equipment is mounted on multi-gage trucks and may be operated in most countries of the world. One of each type of car has been built and is presently in storage at Ft. Holabird, Md. Generally speaking, the domestic railways of the U.S. have developed a high degree of human engineering participation both in the design and safety fields but a lot more remains to be done in both fields, for U.S. Army railway equipment engaged in overseas operation.

Most military railroad rolling stock and control equipment is commercial equipment utilized by the armed forces. The primary

human consideration in all railroad work and equipment is safety. The outstanding safety feature in railroad work is the "Deadman" throttle. The "Deadman" throttle is operated on the same principle as the accelerator on an automobile; pressure must be constantly applied against the throttle to keep it actuated. Should anything happen to the operator and force him to lose control of the throttle, the locomotive will come to a halt.

Automatic block control systems are incorporated everywhere to prevent human errors from misaligning the block or yard and causing collisions. The principle is, the green light can be given a train only when all of the track ahead is clear and all the switches properly aligned.

In the design and construction of highway equipment, important factors that must be considered are those conditions which effect the efficiency of the driver and help to eliminate driver fatigue. The efficiency of the operator controls the efficiency of the vehicle, therefore, the comfort of the operator should be given more consideration.

Some of the important factors that are considered in the design of highway equipment are:

1. The drivers seat - this item has a great effect on the driver's safety. The seat is so constructed as to take most of the shock from rough roads rather than letting the driver take all of the shock. The seat may be designed to fit the configuration of the driver's body. To fit the driver's body the seat is made adjustable so as to let the driver's legs rest on the seat with his back up against the back rest. The seat should let the driver's feet rest flat on the floor and at the same time be within easy reach of all pedals. The Marines are now using a seat in their new jeep, the "Mighty Mite", which seems to have all the necessary characteristics to meet the suggestions mentioned above. A well human-engineered seat for the vehicle driver will make driving less of a struggle and avoid "piles" of trouble and irritation for the driver. The Engineer Corps' new "B.A.T.," an earth-moving vehicle, has a new type seat with arm rest which shows that more of the human element is being considered in the design of highway equipment.

2. Driver vision - the windshield should be of such size that a tall driver will not be looking at the top of the frame or a short man can see out without looking into the steering wheel. The windshield and seat must be so designed as to work in conjunction with each other and not force the driver to sit in an uncomfortable position. Also in conjunction with the seat and windshield, side mirrors are being made of such size and in such position as to allow the driver to see both sides of his vehicle without having to sit in an uncomfortable position.

3. The steering wheel - should be designed with the driver in mind. Steering wheels should be in such a position as to allow the driver to rest his arms instead of one which requires the driver to "fight the steering wheel" all the time. Commercial buses and trucks are being designed with the steering wheel in a rather flat position instead of an upright position. This allows the driver to rest his arms while steering the vehicle. Also, the flat position of the steering wheel gives the driver better front vision.

4. Instruments - motor vehicle devices, such as the gear shift, foot pedals, and panel gages, are being located in such positions as to allow the driver to control his vehicle while sitting in a comfortable position. The gear shift is one item in trucks which is usually so located as to require the driver to reach out of his range in order to change gears. The gear shift in trucks should be located close to the driver so that he can simply drop his hand from the steering wheel to the gear shift and change gears without having to reach across the vehicle. The panel gages on motor vehicles are being located in position to allow the driver to see all of his gages at a slight glance.

Other elements, such as loading and maintenance, are also included in the design of highway equipment which have effects on the operators.

1. The height of the cargo bed has to be considered, because it effects loading time as well as fatigue of the loader. With lower cargo beds, the loader has less lifting to do and will be able to load more cargo. Side loading and shorter cargo beds have also been considered to reduce loading time and fatigue. With side loading, the loader has more access to the cargo bed which makes the loading faster and easier.

2. The size of individual pieces of cargo is also being considered in highway transportation in order to reduce loading problems. By reducing packages such as from one hundred pounds to fifty pounds per package, loading can be done faster with less fatigue on the loading crew. Additional equipment such as fork lifts and conveyors are also being incorporated into highway transportation to facilitate loading and unloading.

3. To increase the efficiency of highway transportation, human factors of maintenance are considered:

a. The accessibility of parts and assemblies is given much time in design of motor vehicles to reduce maintenance time and cost. Certain assemblies such as the generator are usually found at the base of the engine in a place which is very hard to get to without spending a large amount of time. Accessibility of assemblies such as this can be very costly and time consuming on what would be a rather simple job if the generator were placed in a better position. Some of our

present day vehicles are being designed with assemblies, such as the generator, in very accessible positions which shows that the human element in maintenance is being considered more.

b. The present design in trucks is turning more to the cab-over-engine vehicle with a tilt-cab which gives complete access to the engine and assemblies thereby reducing maintenance time and cost. The cab over engine truck with tilt cab is found more in commercial operations, but this concept is being introduced into the military vehicle line, and more will be seen in the future.

The human elements mentioned here have been considered in the past, but they are receiving more attention and will continue to do so in the future. As these elements are considered and vehicle improvements made, highway transportation will also improve.

The "Steerable Fifth Wheel" for semitrailers, developed by U. S. Army TRECOM, is an example of an attempt made to facilitate the driver's work in maneuvering a semitrailer with a consequent saving in time and reduction in fatigue.

Reversing a truck unaided is a fatiguing and difficult maneuver, particularly if the rear window is obscured by the load or by a tarpaulin. The driver in this case must lean out of the window or must hold open the door of the truck, while hanging out of the vehicle like a contortionist. Any device or improvement in design of the vehicle to facilitate reversing would be valuable.

Also we are plugging away at the task of providing better mobility of vehicles over all types of terrain by the use of a new all-terrain tire, which is pneumatic and tubeless. The front wheels are 18"x48"x20", while the rear wheels are 24"x48"x20". The bead die is 20" and the pressure approximately 18 psi - rather low considering size and structures.

The Overland Train, which was discussed at length last year, is still with us but in a neater, more comfortable dress. The newer version of this vehicle is expected to be delivered in November 1960.

The Fluid Transporter provided as a means for movement of bulk fuels over snow and ice, across marshes, deserts and other adverse terrain can be used to provide mobile fuel replacement of motor vehicles, including tanks and armored vehicles. It can also be used to provide mobile stowage of fuels.

One of our most important logistical missions is the supply and maintenance of more than 5,000 Army aircraft. We have spared neither effort, money, nor personnel, in the drive to make our material system highly responsive to the needs of the aircraft user. We have made considerable advance in this highly complex business, and other advances are expected.

Aside from the altruistic consideration, the machine that is comfortable and convenient will yield longer hours of safer operation. The controls of a machine can be systematized in such a way as to prevent thoughtless or accidental actuation of the machine.

VI. U.S. ARMY CHEMICAL CORPS PRESENTATIONS

1. Abstract (Unclassified) of CONFIDENTIAL Presentation: "CBR CONTRIBUTION TO FIREPOWER" by Colonel Ronald R. Martin, U. S. Army Chemical Corps, Research and Development Command.

In any consideration of firepower, two facets must be considered. One aspect consists of systems, devices, or methods used directly against the enemy to destroy or incapacitate men and materiel. The other aspect consists of systems, devices, or methods used by friendly troops to protect themselves from the fire of the enemy. Such items lessen the attrition of men and materiel and, thus, maintain the firepower of our direct offensive capabilities.

The Chemical Corps has made contributions to both aspects of firepower and has many plans for the future in these areas. Some of these areas which the Corps has exploited will be highlighted in this presentation. Categorically, these are:

1. Incapacitating agents - In this area are included riot control agents, non-lethal BW agents, and the newest concept of agents, the psychochemical agents, which affect the mental balance of men.

2. Toxic agents - A large variety of CW, BW and RW agents fall into this class. Current programs are aimed at developing agents which act on men through new channels or which have more effective toxic and mechanical properties.

3. Flame weapons - Flame has become a potent adjunct to more conventional small arms firepower. Its spectacular effect produces a psychological as well as physical bang to flame weapons. A variety of munitions can deliver flame to the enemy, the best known being the portable flame thrower.

4. Wound Ballistics - This program is aimed at determining how wounds are produced and what effects they produce on the entire body. The results of this program should provide data for the development of more effective munitions and better defensive techniques through advanced medical practice and the development of body armor.

5. Agent dissemination systems - This area includes studies aimed at improving present munitions and developing new methods of carrying agents to the enemy.

6. Defensive measures - In this area fall physical protection, i.e. masks and shelters, and medical protection, inoculation and chemical prophylaxis. This latter area holds great promise as a strong defense against enemy CW and BW, and perhaps RW measures. Also included here are the many CBR detectors and alarm systems.

7. Screening agents - Besides screening smokes, a proven weapon, new materials which prevent infra-red and radar surveillance by blocking their searching beams are being developed.

In many of these areas the human is the target, and his many and varied characteristics are the parameters which establish the basic requirements for the development of effective agents and weapons. In others, especially protection, the human either operates or actually wears some device. The value of these devices depends on how well they are designed to fit the characteristics of the human using them.

Many of the problems which arise can be handled by "classical" human engineering techniques, but the Chemical Corps needs new ideas and method in many areas. The extension of knowledge of the relationship of a single individual to a system to the relationship of a group of men to a system is one example of the problems which now face the Chemical Corps.

2. Abstract (Unclassified) of CONFIDENTIAL Presentation: "EFFECTS OF CERTAIN CHEMICALS ON OPERATIONAL TASKS" by Dr. Earl Davy, Chief, Psychology and Human Engineering Branch, Medical Research Directorate, U. S. Army Chemical Warfare Labs, Army Chemical Center.

Among current investigations a major project has the purpose of predicting the effects of incapacitating agents upon the operation of complex military equipment. Toward this purpose a series of laboratory tests are being selected, both from among existing standardized tests and from measurement techniques now being developed at the Army Chemical Center. A second approach involves field tests during which

standard and candidate chemical agents are administered to persons actually using operational equipment or, in some instances, corresponding simulators. We are especially interested in the effects of these agents upon command and decision functions and upon communications among persons engaged in the operation of fire control systems.

VII. U.S. ARMY QUARTERMASTER CORPS PRESENTATIONS

1. Abstract (Unclassified) of CONFIDENTIAL Presentation: "REQUIREMENTS FOR PASSIVE PROTECTION IN ARMY AIRCRAFT", by Captain Thomas H. Burkhalter, QMC, Environmental Protection Division, Quartermaster Research and Engineering Laboratories.

The development of an optimal system of protection for aircrew and aircraft involves the consideration of the total man-equipment-environment system as well as the mission to be accomplished. In an effort to give proper weight to all relevant factors, the present study was conducted by a team composed of highly qualified technical personnel from each of the Technical Services and CONARC.

Phases of the systems study included defining the priority of the aircraft to be studied, defining the probable missions of the aircraft in terms relevant to its vulnerability, estimating the battlefield conditions when engaging a potential enemy, determining the technical characteristics of possible combinations of aircraft and body armor, studying critical aspects of pilot performance and pilot wounding, and an evaluation of effects of location and weight of armor on technical characteristics of aircraft.

Results of the cellation and interpretation of the data, as well as new research efforts generated as a result of the systems analysis, are discussed.

2. "A MATHEMATICAL MODEL FOR PREDICTING LINE-OF-SIGHT CHARACTERISTICS OF TERRAIN" by Dr. Walter F. Wood, Environmental Protection Research Division, Quartermaster Research and Engineering Laboratories.

Introduction

Recent developments in line-of-sight communication and surveillance equipment, both military and civilian, make it desirable to analyze the geometric properties of the earth's surface which affect operation of such equipment. To graphically study terrain obstructions to lines of sight for any significant portion of the world would be impractical. It is desirable then, to develop a method for quickly ascertaining line-of-sight information. Predictive methods have been used successfully in other terrain studies and similar techniques may be applicable to line-of-sight analysis. (3,4)

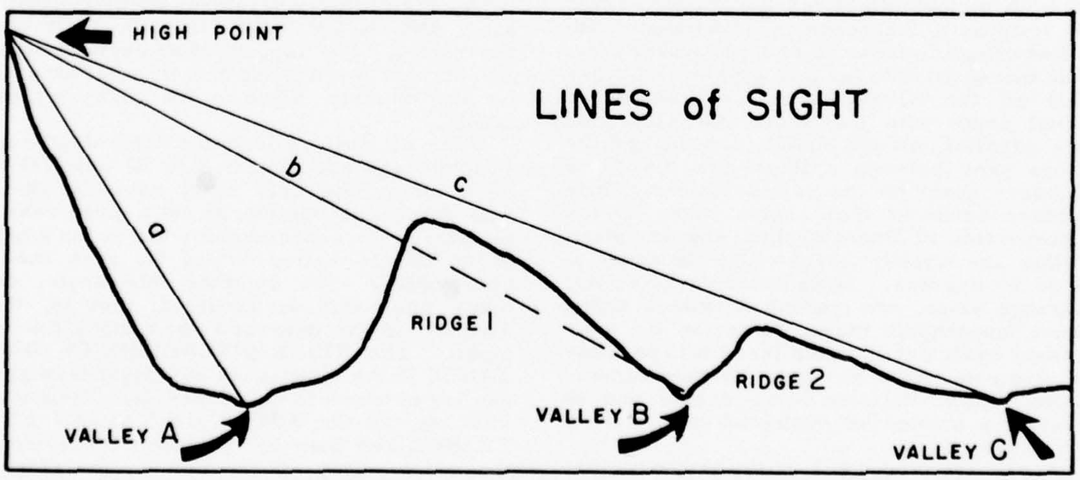

Figure 1. Lines of sight (a, b, and c) projected from high point towards valleys (A, B, and C). Valleys A and C are visible from the high point, valley B is shadowed by ridge 1. Valley B is a protected valley.

The problem defined

To establish a method for predicting line-of-sight information, the capabilities of line-of-sight equipment and dimensions of terrain affecting it will be considered. A first analysis of the situation is limited to that type of equipment which has line-of-sight capabilities up to 20 miles over the smooth earth. This permits the consideration of a portion of the earth's surface as a plane, rather than as a segment of a sphere. Furthermore, since the bottoms of valleys are the most difficult points to see from any distance, the analysis is limited to the ability to see into valleys from a specified point (Figure 1).

The problem is now defined: "From the highest point within an area, how many valley bottoms can be seen at specified distances from that high point?" The results will be expressed as a number of protected (not seen) valleys.

Whether or not valleys can be seen from a point will depend on the character of the valleys and the nature of terrain lying between the high point and the valley. Therefore, the dimensions of terrain which most obviously affect line of sight will be the differences in elevation between the valleys and this high point (relief), the slope of the surface between them, the distance between valleys (valley spacing), and the depth of valleys. All of these dimensions can be computed from data available on topographic maps. With such information at hand, it is possible to construct a mathematical model of the terrain from which predictions of valley visibility can be made.

A mathematical model

a. Concepts under-lying construction of the model

A mathematical terrain model serves to simplify a landscape in accordance with a few actual dimensions of a particular area. The model devised for this problem assumes that all the valleys within the area are of equal depth with the same side-slope, all are parallel, all are equally spaced, and the ridge tops between valleys are the same distance apart as the valley bottoms. It is further assumed that angles made by the intersection of lines-of-sight and any given valley are equally likely within the range of 0 to 90 degrees. Measurements of relief, average slope, and spacing of valleys, taken from topographic maps, comprise the necessary basic data. From these it is possible to compute other pertinent terrain dimensions which will, in turn, enable one to predict a number of protected valleys for a given area.

A general discussion of the mathematical terrain model follows. The construction and test with actual dimensions will be presented in the following section. RELIEF is the difference between the highest and lowest points within a unit area. The measure for AVERAGE SLOPE is obtained by counting the number of contour lines crossed by a random traverse and processing this information by an equation:

$$(2) \qquad S\ \tan = (I \times M)/3361;$$

where "S tan" is the average slope tangent; "I" is the contour interval of the map in feet; and "M" is the number of contours crossed per mile of random traverse.

The average VALLEY SPACING is determined by counting the number of valleys along a random traverse and processing this number by the equation:

$$(3) \qquad S = (T/N)/1.57;$$

where "S" is the average valley spacing; "T" is the length of traverse; "N" is the number of valleys along the traverse. The constant "1.57" compensates for the fact that the valleys do not intersect a circle at right angles.

Other dimensions necessary for solving the line-of-sight problem include the distance from a ridge top to a valley bottom. Assuming that ridge tops are the same distance apart as valley bottoms, the RIDGE - VALLEY DISTANCE within the area will be one-half the valley spacing. An average VALLEY DEPTH can be computed from the average slope and the ridge-valley distance. For instance, the average slope tangent of the area is .15 and the ridge-valley distance is one mile, the valleys are .15 miles deep. (.15 x 1 = .15)

The angle a line of sight makes between the highest and lowest points at a given distance also contributes to the solution of valley visibility. Therefore, another dimension, ANGLE OF SIGHT must be built into the model. The tangent of an angle of sight is obtained by dividing the relief of an area by the distance between the high and low points.

When all valleys have the same depth and spacing, and are assumed to be parallel to each other, the only other variable which will determine whether or not a given valley is seen from a particular point is the angle at which the valley enters the area under observation. To compute this angle, one other dimension is required, that is, the distance to the nearest ridge along a line of sight. The RIDGE-INTERFERENCE DISTANCE IS the hypotenuse of a right triangle, one leg of which is the ridge-valley distance. The sine of the ANGLE OF VALLEY ENTRANCE can then be computed by dividing the ridge-valley distance by the ridge-interference distance. It is the angle of valley entrance which is converted to a percent of total valleys protected.

The valley which enters an area directly toward the point from which a line of sight is projected, that is, the valley which is an extension of the line of sight, will always be seen. For any given valley depth, spacing and angle of sight, there is a given angle of entrance at which a valley can just barely be seen. Those valleys which make an even more acute angle with the line of sight can also be seen, but those which are at a greater angle cannot be seen. Thus, when this angle of valley entrance divides a right triangle, said to contain all the valleys in a given area, into two parts, the section of the triangle which lies to one side of the line formed by this angle, is analagous to the proportion of valleys seen in that area; the section of the triangle which lies to the other side of this line, is analagous to the proportion of valleys which cannot be seen.

b. The model applied to specific areas

In order to test its validity, the mathematical model described above was applied to two areas of widely contrasted terrain. The areas selected were in New England (Glens Falls sheet, 1:250,000 AMS series, contour interval 100') and the Colorado Plateau (Grand Canyon sheet, 1:250,000 AMS series, contour interval 200'). The Glens Falls sheet represents a mountainous area of many, deep, closely-spaced valleys and steep slopes. In contrast, the Grand Canyon region is plateau country with fewer, widely-spaced valleys and less steep slopes.

For both areas, the following technique for gathering data and predicting number of protected valleys was followed:

(1) The highest elevation on the sheet was selected as the point from which lines of sight would be projected towards the valleys within the area.
(2) The study was limited to a circular area having a radius of 20 miles with the highest point on the sheet as the center of the circle.
(3) 20 concentric circles were drawn at intervals of 1 mile from the highest point.
(4) Every stream (indicating a valley) crossing a circle was analyzed to see whether or not it was visible from the highest point. Lines of

TABLE I

NUMBER OF PROTECTED VALLEYS DETERMINED FROM LINE-OF-SIGHT OBSERVATION

Radius of Circle	GLENS FALLS SHEET AMS 1:250,000			GRAND CANYON SHEET AMS 1:250,000		
	Number of Valleys Crossing Circles	Number of Protected Valleys	Percent Protected	Number of Valleys Crossing Circles	Number of Protected Valleys	Percent Protected
1 mile	4	1	25	0	0	0
2 miles	7	4	57	1	0	0
3 miles	12	9	75	3	1	33
4 miles	10	7	70	3	1	33
5 miles	13	9	69	6	4	67
6 miles	12	5	42	8	3	38
7 miles	20	12	60	10	5	50
8 miles	25	20	80	11	5	45
9 miles	17	10	59	8	5	63
10 miles	21	9	43	16	11	69
11 miles	27	15	56	16	10	63
12 miles	33	20	61	17	10	59
13 miles	32	19	59	23	11	48
14 miles	36	27	75	24	14	58
15 miles	32	22	69	26	17	65
16 miles	35	27	77	29	18	62
17 miles	40	34	85	33	19	58
18 miles	44	42	95	35	13	37
19 miles	41	36	88	38	10	26
20 miles	41	40	98	35	17	49

TABLE II

COMPUTATIONS FOR CONSTRUCTING TERRAIN MODEL TO PREDICT NUMBER OF PROTECTED VALLEYS

20-mile circle, Glens Falls sheet, AMS 1:250,000

TERRAIN FACTORS	FORMULA for COMPUTING	COMPUTATIONS	RESULTS
A Radius of circle			20 mi.
B Circumference of circle	$2\pi r$	2 x 3.1416 x 20	125.66 mi.
C Number of valleys crossing circle			41
D Relief (in miles)	Highest elevation -Lowest elevation	4000 ft. - 330 ft. = 3670 ft.; 3670 ÷ 5280	.6951 mi.
E Average slope tangent	$\frac{\text{contour counts/mi. x contour interval}}{3361}$	$\frac{4.84 \text{ cc/mi. x } 100'}{3361}$	.1440
F Valley spacing	$\frac{\text{traverse} \div \text{valley number}}{1.57}$	$\frac{125.66 \div 41}{1.57}$	1.9512 mi.
G Ridge-valley distance	$\frac{\text{valley spacing}}{2}$	$\frac{1.9512}{2}$	.9756 mi.
H Valley depth	average slope ridge-valley distance	.1440 x .9756	.1405 mi.
I Angle of sight (tangent)	$\frac{\text{relief}}{\text{radius}}$	$\frac{.6951}{20}$	.0348
J Ridge-interference distance	$\frac{\text{valley depth}}{\text{angle of sight}}$	$\frac{.1405}{.0348}$	4.0374 mi.
K Angle of valley entrance (sine)	$\frac{\text{ridge-valley distance}}{\text{ridge-interference distance}}$	$\frac{.9756}{4.0374}$	.2416
L Angle of valley entrance (degrees)			13.98°
M Percent of valleys seen*	angle of valley entrance ÷ 90°	$\frac{13.98}{90}$	15.53%
N Percent of valleys protected	100% - % of valleys seen	100% - 15.53%	84.47%
O Predicted number of protected valleys	% of protected seen	84.47% x 41	35

*Computing the percent of valleys seen is facilitated on a desk-type calculator by using the reciprocal of 90 (1.1111) as a multiplier. Thus, this formula becomes: **Angle of valley entrance x 1.1111.**

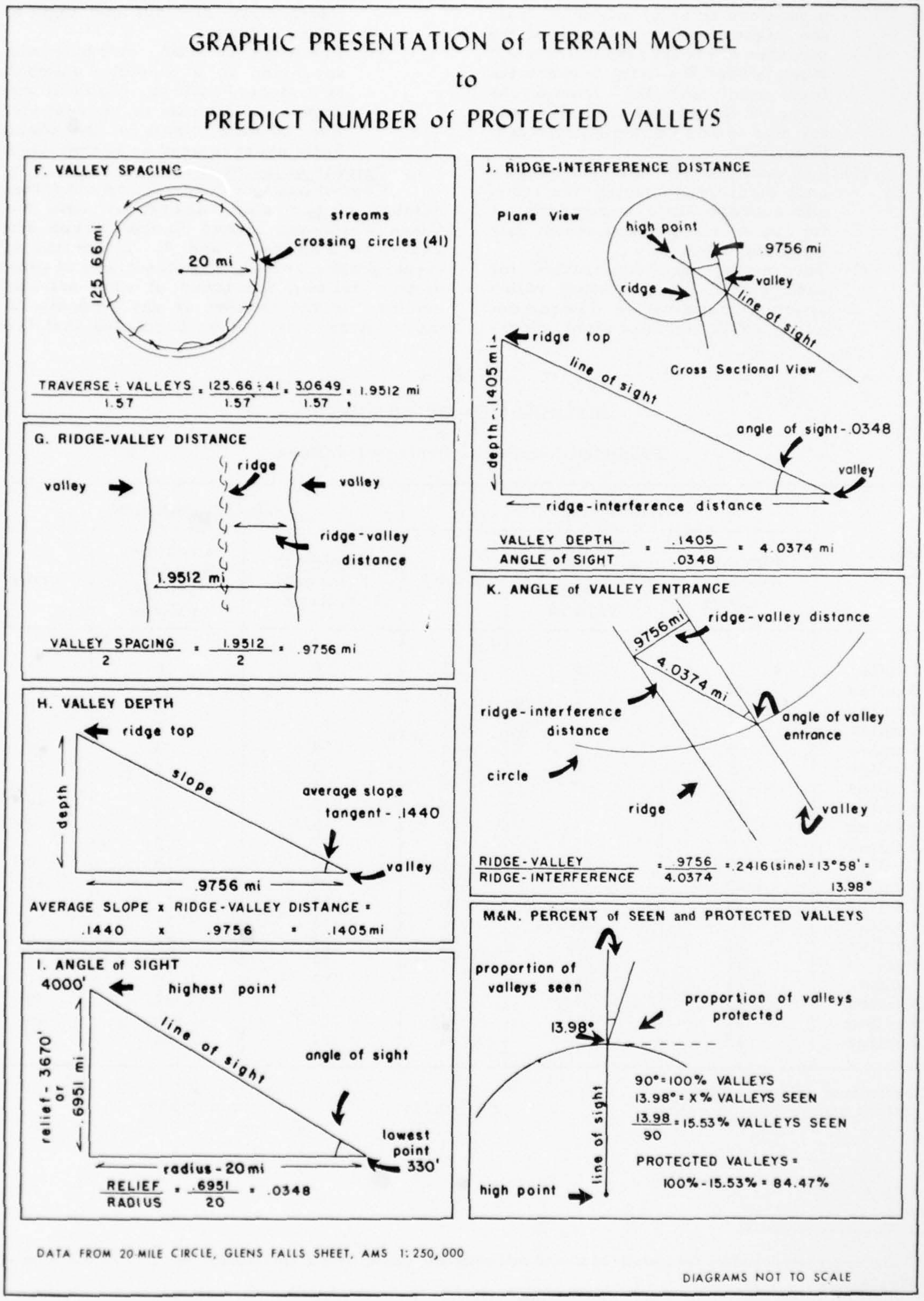
GRAPHIC PRESENTATION of TERRAIN MODEL
to
PREDICT NUMBER of PROTECTED VALLEYS
F. VALLEY SPACING
streams
crossing circles (41)
20 mi
125.66 mi
TRAVERSE ÷ VALLEYS / 1.57 = 125.66 ÷ 41 / 1.57 = 3.0649 / 1.57 = 1.9512 mi
G. RIDGE-VALLEY DISTANCE
ridge
valley
valley
ridge-valley
distance
1.9512 mi
VALLEY SPACING / 2 = 1.9512 / 2 = .9756 mi
H. VALLEY DEPTH
ridge top
slope
depth
average slope
tangent - .1440
valley
.9756 mi
AVERAGE SLOPE x RIDGE-VALLEY DISTANCE =
.1440 x .9756 = .1405mi
I. ANGLE of SIGHT
4000'
highest point
line of sight
angle of sight
relief - 3670' or .6951 mi
lowest point
330'
radius - 20 mi
RELIEF / RADIUS = .6951 / 20 = .0348
J. RIDGE-INTERFERENCE DISTANCE
Plane View
high point
.9756 mi
valley
ridge
line of sight
ridge top
depth - .1405 mi
line of sight
Cross Sectional View
angle of sight - .0348
valley
ridge-interference distance
VALLEY DEPTH / ANGLE of SIGHT = .1405 / .0348 = 4.0374 mi
K. ANGLE of VALLEY ENTRANCE
.9756 mi
ridge-valley distance
4.0374 mi
ridge-interference
distance
angle of valley
entrance
circle
ridge
valley
RIDGE-VALLEY / RIDGE-INTERFERENCE = .9756 / 4.0374 = .2416 (sine) = 13°58' =
13.98°
M&N. PERCENT of SEEN and PROTECTED VALLEYS
proportion of
valleys seen
proportion of valleys
protected
13.98°
90° = 100% VALLEYS
13.98° = X % VALLEYS SEEN
13.98 / 90 = 15.53% VALLEYS SEEN
PROTECTED VALLEYS =
100% - 15.53% = 84.47%
line of sight
high point
DATA FROM 20-MILE CIRCLE, GLENS FALLS SHEET, AMS 1:250,000
DIAGRAMS NOT TO SCALE

Figure 2

sight were actually projected from the highest point to each of the streams where it crossed a circle.* When elevations lying between the high point and the stream obstructed the line of sight, the valley was considered protected. (Table I)

(5) The number of valleys crossing each circle was counted; the relief and average slope were computed for each circle, and these data were recorded.

(6) The model was constructed for each circle by computing valley spacing, ridge-valley distance, valley depth, angle of sight, ridge-interference distance and angle of valley entrance.

(7) The angle of valley entrance was converted to a predicted number of protected valleys. (Table II and Figure 2 illustrate these methods. The 20-mile circle of the Glens Falls sheet is used as an example.)

c. Validity of the model

Comparisons of the predicted and actual number of protected valleys for both the Glens Falls and Grand Canyon areas are shown in Figures 3 and 4. Inspection of these graphs reveals that the trend of prediction follows the trend of what actually occurs. In the absence of any evidence to the contrary, it can be concluded that the

TABLE III

DISTRIBUTION OF ERRORS

Predicted Number of Protected Valleys

Radius of Circle	GLENS FALLS			GRAND CANYON		
	Number of Protected Valleys	Predicted Number of Protected Valleys	Error	Number of Protected Valleys	Predicted Number of Protected Valleys	Error
1 mile	1	0	-1	0	0	0
2 miles	4	4	0	0	1	+1
3 miles	9	7	-2	1	1	0
4 miles	7	6	-1	1	1	0
5 miles	9	8	-1	4	3	-1
6 miles	5	8	+3	3	4	+1
7 miles	12	13	+1	5	6	+1
8 miles	20	17	-3	5	7	+2
9 miles	10	12	+2	5	5	0
10 miles	9	15	+6	11	10	-1
11 miles	15	20	+5	10	10	0
12 miles	20	25	+5	10	11	+1
13 miles	19	25	+6	11	11	0
14 miles	27	28	+1	14	11	-3
15 miles	22	26	+4	17	14	-3
16 miles	27	28	+1	18	17	-1
17 miles	34	33	-1	19	20	+1
18 miles	42	36	-6	13	22	+9
19 miles	36	34	-2	10	19	+9
20 miles	40	35	-5	17	24	+7

Coefficient of correlation: actual and predicted values — Glens Falls: r = .9613; Grand Canyon: r = .8597

* A new device which permits the analysis of line-of-sight problems without drawing earth profiles, was used for this phase of the study. (1)

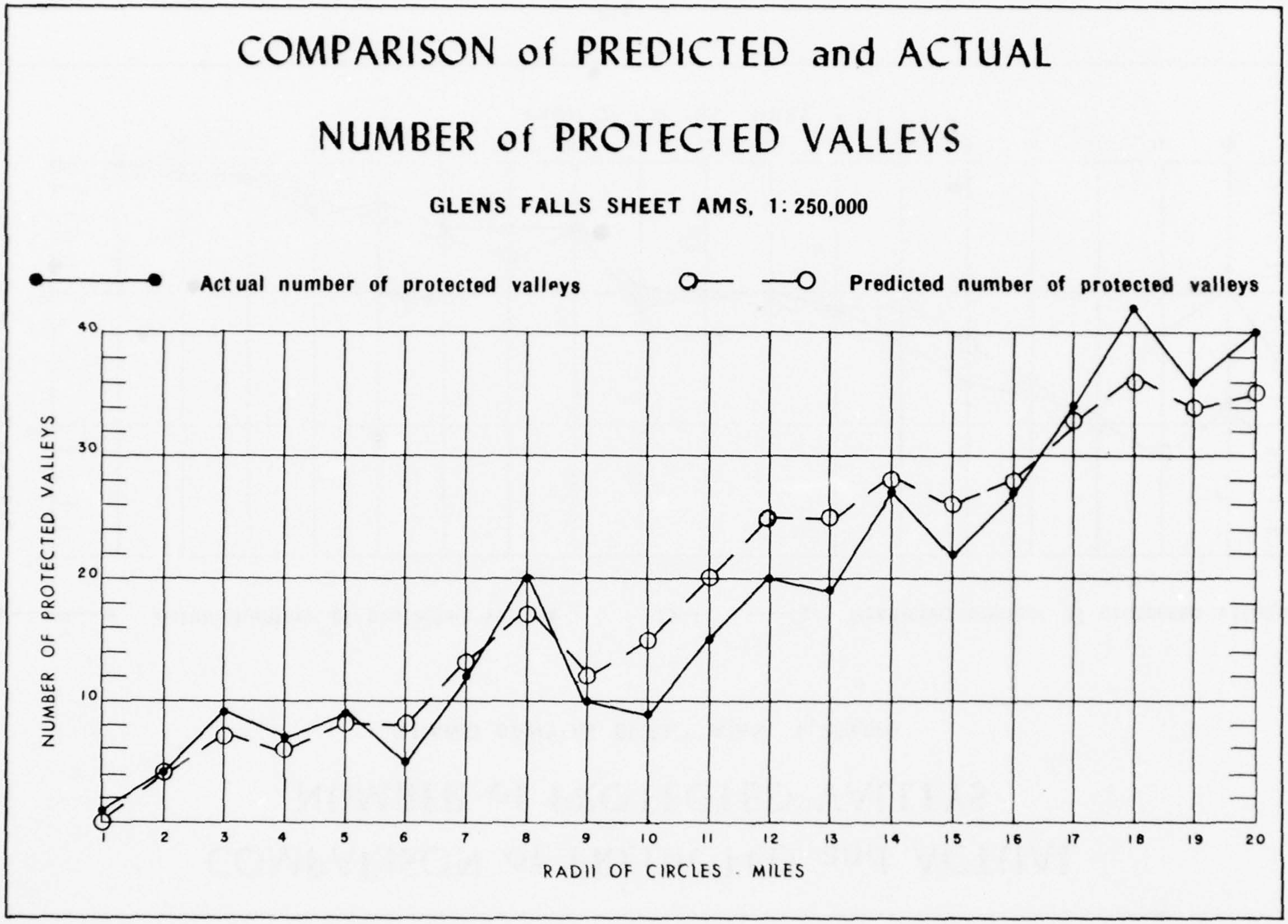
COMPARISON of PREDICTED and ACTUAL
NUMBER of PROTECTED VALLEYS
GLENS FALLS SHEET AMS, 1: 250,000
Actual number of protected valleys
Predicted number of protected valleys
NUMBER OF PROTECTED VALLEYS
40
30
20
10
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
RADII OF CIRCLES - MILES

Fig. 3

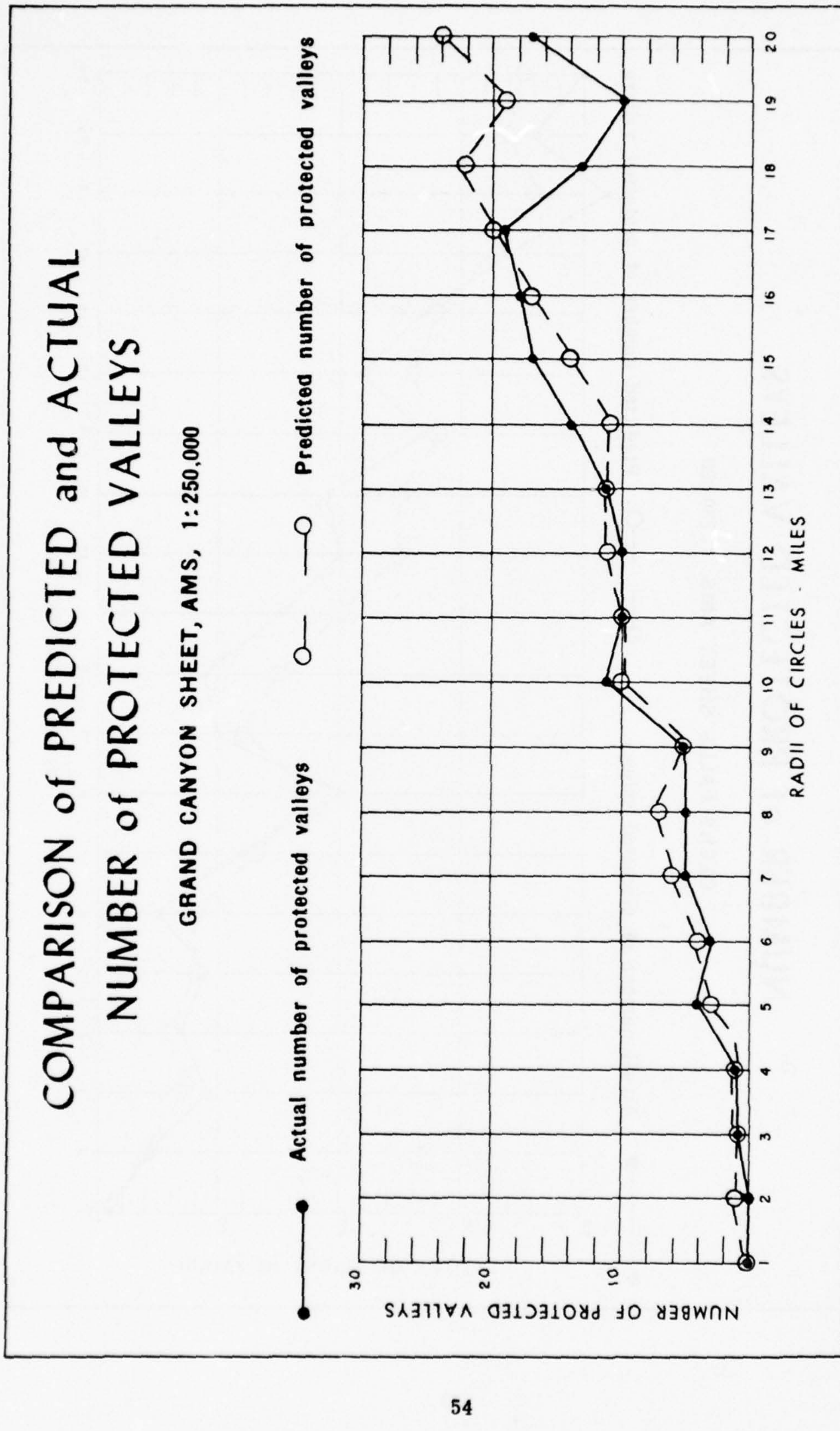
COMPARISON of PREDICTED and ACTUAL
NUMBER of PROTECTED VALLEYS
GRAND CANYON SHEET, AMS, 1:250,000
Actual number of protected valleys
Predicted number of protected valleys
NUMBER OF PROTECTED VALLEYS
30
20
10
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
RADII OF CIRCLES · MILES

Fig. 4

model is valid in theory, and unless further tests prove otherwise, it can be considered applicable to all terrain.

Although the trend line (Fig. 3 and 4) indicate that the model is promising, improvements can probably be made. Further research into the line-of-sight problem will seek means of overcoming the existing error (Table III) and extending the application of line-of-sight information.

Suggested lines of study for further investigations into the problem

a. Randomness of valley entrances

The construction of the model and subsequent predictions are based on the assumption that the angles at which valleys cross a line-of-sight have a random distribution. Thus, the first consideration in perfecting the model would be the analysis of any deviation from randomness exhibited by these angles. Probability laws will definitely limit the accuracy of any improvements made in the model and it should be known how important this is so that effort is not wasted in trying to obtain a performance level which is impossible.

b. Blocking effect

In developing the model, the only height of land considered capable of blocking a line of sight into a valley was the ridge nearest the valley. A study of the actual lines of sight, and the pieces of terrain which blocked them, showed that in many cases, high land further away from the valley exercised the blocking effect. The relative position of such high land, with regard to sighting point and valley, requires further investigation. The pattern of prediction errors (Figs. 3 and 4) suggests that the grain of the landscape is involved.

Landscape grain is determined by the spacing of the major ridges and valleys. It is computed by selecting a random point on a map and drawing circles at even increments of diameter around this point. The relief for each circle is plotted against its diameter and the points connected with a straight line. At some length of diameter, a knick point will occur in this line, after which, with increasing size of area, there is no appreciable increase in relief. The length of diameter at which the knick point occurs is the grain of the area. (Fig. 5)

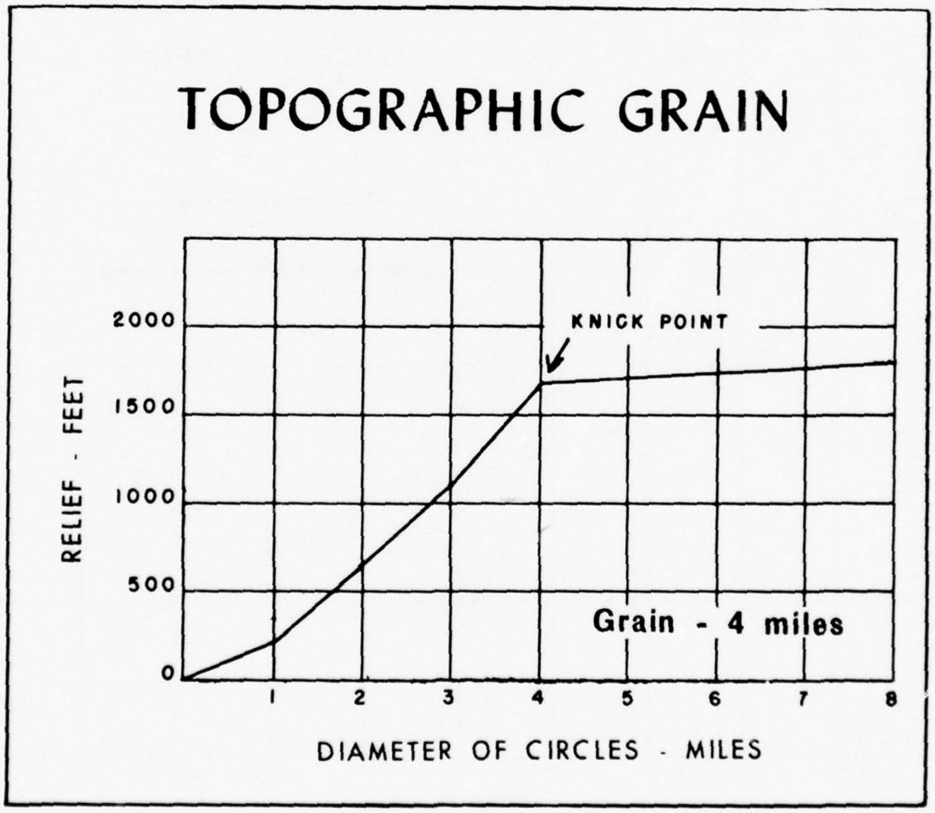

Figure 5. Landscape grain is determined by plotting relief of a circular area against diameter of a circle and noting the diameter at which a knick point occurs.

Grain in the Glens Falls area occurs at about the 7-mile circle. Figure 3 and Table III show that the model worked best in the first 7 circles, with a tendency toward under-prediction. The next group of 7 circles tended toward over-prediction and less accurate predictions. After about the 14-mile circle, the performance of the model was more like that of the first 7 circles. In the Grand Canyon, the grain is at the 14 mile circle. From Figure 4 and Table III, good performance of the model is evident up to the 14-mile circle, after which the performance becomes poorer and tends toward over-prediction.

c. Selection of a point from which to project lines-of-sight

To develop the technique described above, the highest point within the area under observation was selected as the point from which lines of sight were projected. Since no land is higher than this point, it is presumably, the optimum location from which to keep the entire area under surveillance. The question arises, however, as to the effectiveness of lines-of-sight when the sighting point is at some elevation other than the highest in the area. In an attempt to answer this query, the elevations of over 600 random points from the 20-mile circle on the Glens Falls sheet were plotted against percent of area. Thus a chart was produced that shows the percent of total area which lies above any specified elevation (Fig. 6). This chart can be used as an aid to obtain an impression of the suitability of a sighting point at some elevation other than the highest within the area.

For example, if a sighting point were selected at an elevation of 2920 feet, 1% of

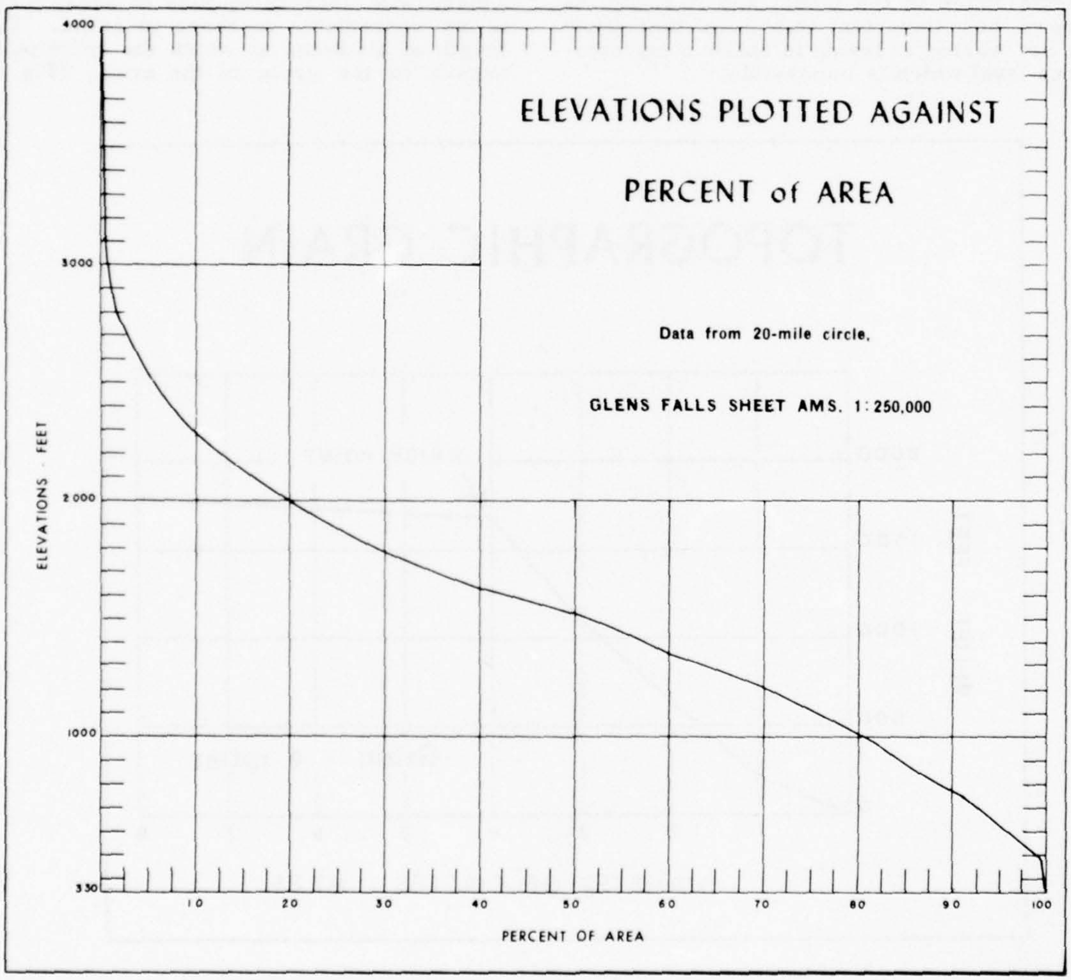

Figure 6

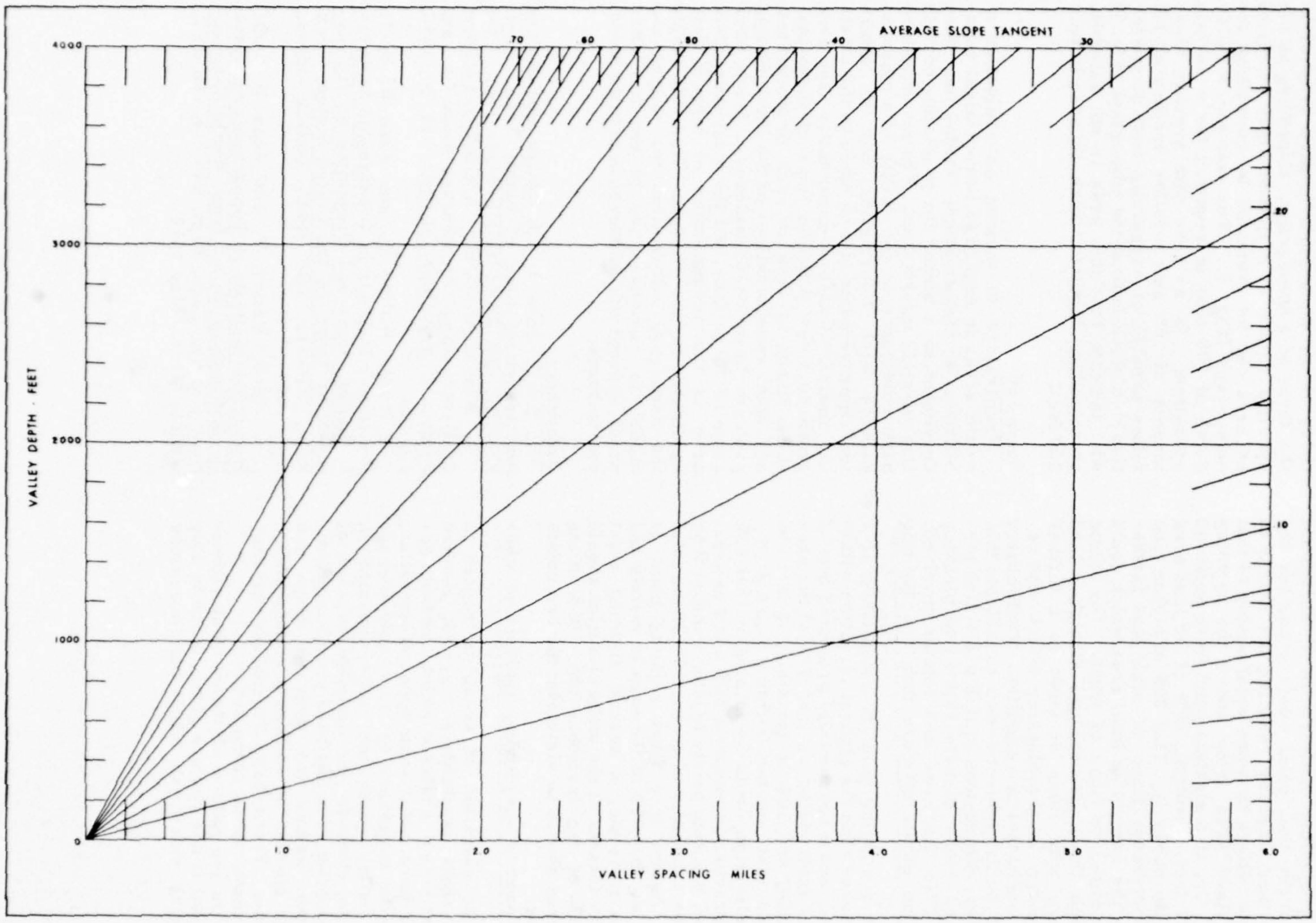

Fig. 7 Nomograph to determine the numerical relationships of valley depth, valley spacing, and average slope.

the total area would lie above it. Lines of sight projecting outward in a horizontal plane from this point would encounter the higher land, thereby reducing the ability to see into valleys by some relationship to that 1% of land area lying above the sighting point. Or, if a sighting point were selected at 2000 feet elevation, 20% of the land area would lie above it. This 20% of higher land would interrupt lines of sight and further reduce the amount of total area which could be traversed by lines of sight. The extent to which these percentages of higher land interfere with lines of sight is a further ramification of the blocking effect, and requires additional investigation. Preliminary thought on the subject seems to indicate that the linear dimensions of this projecting terrain are more closely related to blocking effect than the area and volume involved.

d. The effect of more than one sighting point

If a sighting point is established at a place lower than the highest elevation within an area, and a horizontally projected line of sight is interrupted so that 99% of the area is visible, and 10% is invisible, it is to be expected that another sighting point at the same elevation could be located so that 90% of the previously invisible 10% could be seen. The two sighting points together should then have the capability of seeing 90% of the total area. Again, if a first sighting point is placed so that 80% of the area is visible and 20% is invisible, a second sighting point properly located at the same elevation should see 80% of the invisible 20%. 96% of the total area should be visible to the two points together.

e. Towards simplifying analysis of other areas

The elevation of areas in regard to line-of-sight capabilities may not require the detailed analysis which has been described here. For some types of operation, it may be necessary to know only average slope, valley depth and valley spacing in order to evaluate the expected success of that operation. As has been previously demonstrated, values for average slope and average spacing of valleys are not difficult to obtain. From these dimensions, average valley depth can be computed.

It is in the nature of these three dimensions that if any two are given, there is only one figure which will fulfill the dimensions of the third. Therefore, the relationship of these three dimensions can be graphed in the form of a nomograph. Depending on the specific nature of a line-of-sight problem, an area can be evaluated by consulting the nomograph (Fig. 7). For example, a valley depth of 500 feet is required for a certain operation. Is an area with average slope tangent of .08 and a valley spacing of 1.2 miles capable of supporting such an operation? A quick look at the nomograph (Fig. 7) will indicate that this area is not suitable, since valley depth for such an area is only 250 feet.

Summary

Preparatory to making an evaluation of world areas in regard to line-of-sight capabilities, a mathematical model has been developed as a means for predicting certain line-of-sight information. The investigators have confidence in the ability of a model to provide such information, but are aware that improvements can be made in the existing model. Cursory examination has been given to a few possible lines of investigations likely to lead to such improvement, and other considerations of the line-of-sight problem have been explored. Much work remains to be done, but the most immediate need is the accumulation of terrain data applicable to line-of-sight. This will supply the necessary information for testing the model in various types of terrain, after which appropriate improvements in the model can be made.

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VIII. U.S. ARMY SIGNAL CORPS PRESENTATION

VALIDATION OF EVALUATION

By R. E. Frese
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The term "human factors" is used to denote the interaction of human beings with the things they do. Human factors applies to many things because of the variety of human activity. One of the more challenging human endeavors is relative evaluation. We do it almost constantly. At this moment you are evaluating the quality of my paper and its presentation in comparison with the others that have been presented.

We seldom analyze and validate the process by which we evaluate. Analysis and validation are unnecessary when only ourselves must be satisfied. We trust our own judgment and our personal standards and we can rationalize our procedures if necessary.

When others are involved we frequently disagree. We buy different automobiles and keep them different lengths of time. We hear many arguments about matters of evaluation, consumer goods, sports, and even our technical work; we also see newspaper reports of loss of life due in part to differences of opinion in evaluation.

The outcome of a particular evaluation depends upon the relative importance placed upon many factors which enter into it and upon the standards used. The validation procudure I will describe today is one that applies to the actual data that you have and it has been designed to answer two important questions:

1. Has the assignment of relative importance to the factors been sufficiently precise in this evaluation?

2. Do significant differences exist among the evaluated items?

The procedure which answers these questions is applicable to numerical evaluation processes which are used frequently when the items to be evaluated are complex. The example which Colonel Ewbank gave yesterday of a tank which must be light, float, have heavy armor and have a big gun is representative of complex evaluation. Because we can only approach all the desirable characteristics a tank must have, we are forced to compromise. It is conceivable that a numerical evaluation procedure would be used to assist such a compromise, in the selection of a particular item from a set of competing designs or models. There are many complex systems and designs that have been and may be subjected to numerical evaluation procedures.

The prerequisite to numerical evaluation is prescreening. We resort to numerical procedures only for that portion of an evaluation which we can not manage adequately in other ways. By prescreening, an item is eliminated from consideration in the numerical evaluation because it is clearly unacceptable because of one or more factors, regardless of the other factors which enter into the evaluation. Those partial decisions which can be made without the assistance of numerical evaluation procedures are made. I am sure that most of you have participated in this type of evaluation at one time or another. I will describe this type of evaluation by reference to a particular example.

Figure 1 illustrates a completely ficticious example described in Signal Corps terms. A number of two-way radio equipments are to be evaluated for a particular use by a series of tests and inspections. Individual evaluators or groups of them are assigned to each of the seven categories listed on the left according to their individual skills. The desired characteristics of the equipment within each category are known. The evaluation is considered from the three different points-of-view, operation in the temperate and tropic and arctic zones. For example: A group is assigned to consider the range of reliable operation of the equipments. Because climatic conditions affect the propagation of radio waves, this group considers the arctic and tropic extremes as well as the temperate. Another group, a human factors group, considers the training required and the ease of operation, installation, and maintenance of the equipments in the three zones. It is sufficient that quality of workmanship and reliability be satisfied only at the environmental extremes, therefore, the temperate box has been eliminated from this category. Note that because weight and size vary little from arctic to tropic, the points-of-view do not apply to this category.

Within each category, the evaluators reduce their value judgments to numerical scores. The scores are entered on a form which is perhaps identical to that in Figure 1;

EVALUATION BREAKDOWN

	POINTS-OF VIEW		
	TEMPERATE	TROPIC	ARCTIC
POWER REQUIREMENTS			
SPURIOUS RESPONSES AND EMISSIONS			
COMPATIBILITY WITH EXISTING EQUIPMENTS			
RANGE OF OPERATION			
TRAINING REQUIRED AND EASE OF OPERATION			
WORKMANSHIP AND RELIABILITY			
WEIGHT AND SIZE			

Figure 1. Breakdown of the Numerical Evaluation Procedure

one form for each of the items; and eighteen scores on each form for each item.

The relative importance of the categories and points-of-view have been defined by numerical weights agreed to in advance for maximum objectivity. Figure 2 shows a plausible but ficticious set of weights that might apply to this evaluation. In this example, weights are assigned to the rows and columns. Individual weights could have been assigned to the individual boxes. The validation procedure to be described can be used regardless of the procedure by which the weights are applied. In every case, the weights must be selected and assigned so that they properly represent the relative importance of factors involved. However, even the most competent of evaluators will question his ability to assign values to the weights exactly. It is normally assumed in this type of evaluation that small changes in the weights do not have a serious effect on the outcome. As I will show, this assumption can get you in trouble. Note that the weight, ten, assigned to weight and size is much larger than the rest to compensate for the fact that the point-of-view weights do not apply.

The individual scores are now multiplied by the corresponding weights and summed to yield a total weighted score for each item. As shown in Figure 3, a score entered in the power requirements - tropic box is multiplied in turn by the weights assigned to both power requirements and tropic. If the score is 4 as shown in the left of the box on the slide, it is multiplied by one for power requirements and two for tropic, yielding a weighted score of eight. For range of operation and temperate, a raw score of 3 is multiplied by 2 for range and 3 for temperate, yielding a weighted score of 18. By this process all the scores are weighted and the weighted scores are then summed. Then the items are ranked according to total weighted score.

In order to study this evaluation process, synthetic scores were generated in the following way. Using a scoring system based on five, in which zero represents unsatisfactory and five represents outstanding, probability distributions for the individual scores were defined as illustrated. A reasonable probability distribution was chosen for item number one as shown in Figure 4. From it, the distribution for item number two was derived by reducing the probability of the largest score by 1/36 and increasing the probability of zero score by 1/36. This is indicated by the portion of the bars which are shaded. To get the distribution for item two the shaded section of the distribution for item one is moved to where it is shown for item two. This process was repeated on down the line for a total of ten items. Then for each item, the 18 required scores were randomly sampled from the corresponding distribution by tossing two dice. Multiplying the scores for the items by the weights shown previously produced the total weighted scores and ranking shown in Figure 5. The small differences among the distributions, of course, only tended to rank the items in numerical order.

Where do we stand as a result of this evaluation procedure? We have a ranking of the items by total weighted score, with item number 6 first. But is there a significant difference among the items, especially among the higher ranked ones? Would the ranking change if small adjustments were made in the value of the numerical weights?

Assume that in agreeing upon the assignment of numerical weights it was also agreed that the values chosen were accurate to about 25 percent. We cannot do much better than this in most circumstances. For example; is range of operation just as important as compatibility or is it one and one quarter times more important? This is an exceedingly difficult refinement to accomplish.

The response of ranking to variation in weights was investigated by the use of a digital computer and a simple routine. Each weight was replaced by the simple distribution of weights which is shown in Figure 6. Three values, the mean and values C percent above and below the mean were equally likely. The mean values were identical to the values used in the evaluation and the constant C was 25 in this case.

The routine for investigating the variation in ranking is described as follows:

Each of the weights is sampled at random from its distribution.

Then the total weighted score is calculated for each item.

Then the items are ranked by total weighted score and the result is stored.

The first three steps are repeated a large number of times, one hundred times for the example we are considering, producing, if there is variation, a distribution of ranks for each item.

Then the arithmetic mean rank and standard deviation of rank for each item is calculated and printed out by the computer.

A general routine can be programmed for the computer which will handle up to any expected number of categories, points-of-view and items, even in the incomplete-block type of breakdown we have in the example presented today. The cost is little; running time for the example is only three minutes on an IBM-709 computer.

This routine was used to investigate the evaluation process. The results of this investigation are presented on the left side of Figure 7 in comparison with the results of the evaluation which are presented on the right. On the right side, the items are arranged by the mean rank of the one hundred

ASSIGNMENT OF WEIGHTS

CATEGORY	WEIGHT
1. POWER REQUIREMENTS	1
2. SPURIOUS RESPONSE AND EMISSION	1
3. COMPATIBILITY WITH EXISTING EQUIPMENTS	2
4. RANGE OF OPERATION	2
5. TRAINING REQUIRED AND EASE OF OPERATION	3
6. WORKMENSHIP AND RELIABILITY	3
7. WEIGHT AND SIZE	10
POINT OF VIEW	**WEIGHT**
TEMPERATE	3
TROPIC	2
ARCTIC	1

Figure 2. Assignment of Weights for the Evaluation

MULTIPLICATION BY WEIGHTS

	POINTS-OF VIEW		
	TEMPERATE	TROPIC	ARCTIC
POWER REQUIREMENTS		4/8	
SPURIOUS RESPONSES AND EMISSIONS			
COMPATIBILITY WITH EXISTING EQUIPMENTS			
RANGE OF OPERATION	3/18		
TRAINING REQUIRED AND EASE OF OPERATION			
WORKMANSHIP AND RELIABILITY	X		
WEIGHT AND SIZE			

Figure 3. Multiplication by Weights

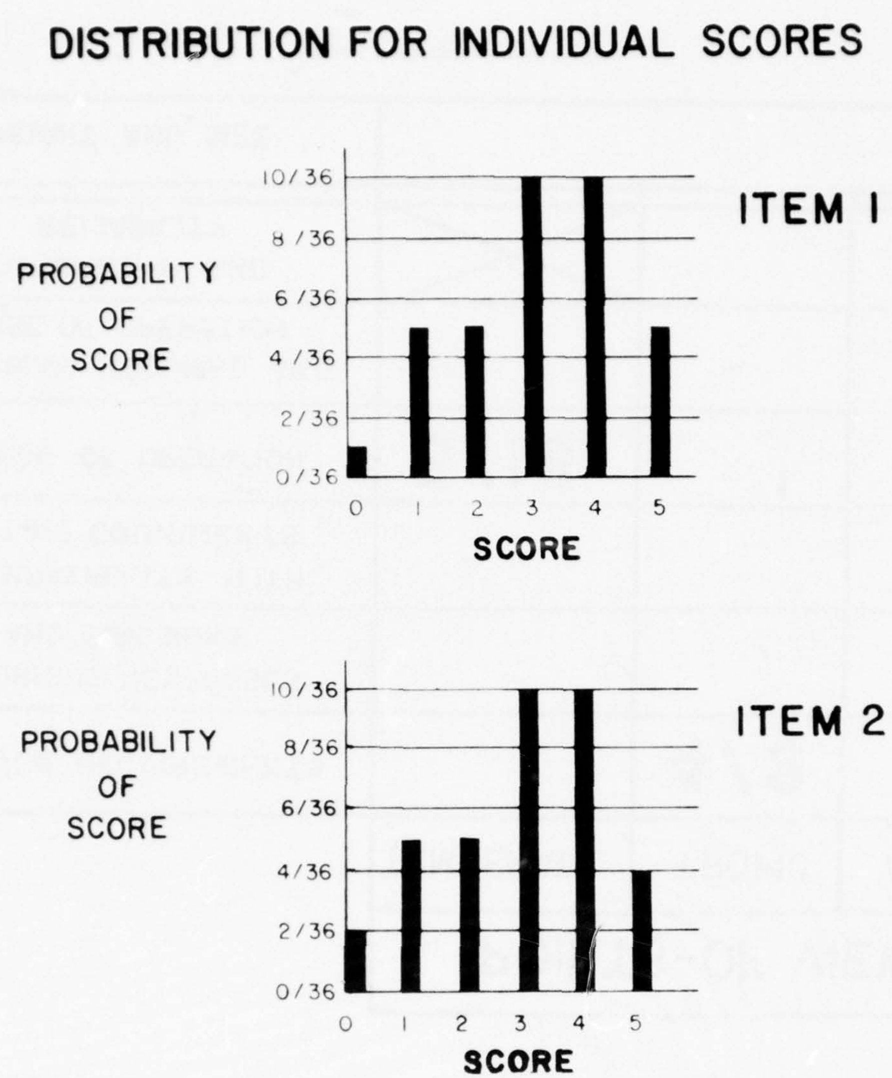

Figure 4. Probability Distribution Used to Obtain Scores for Items One and Two

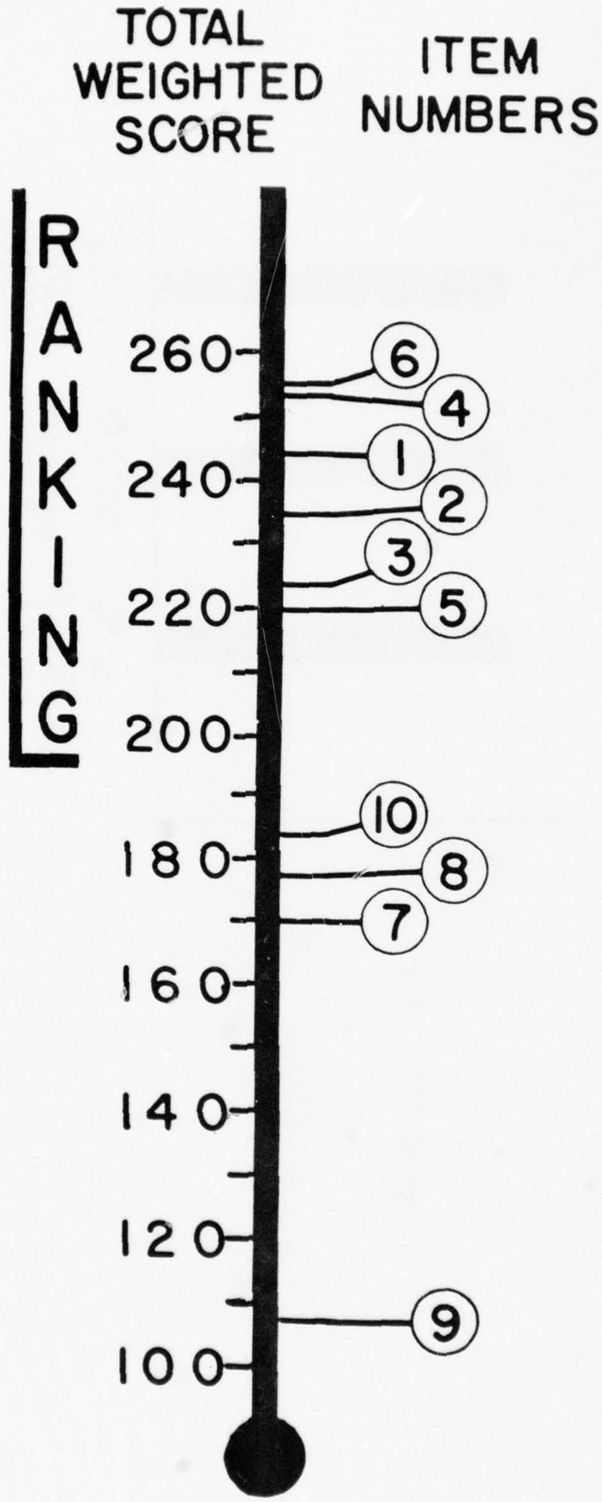

Figure 5. Ranking by Total Weighted Score

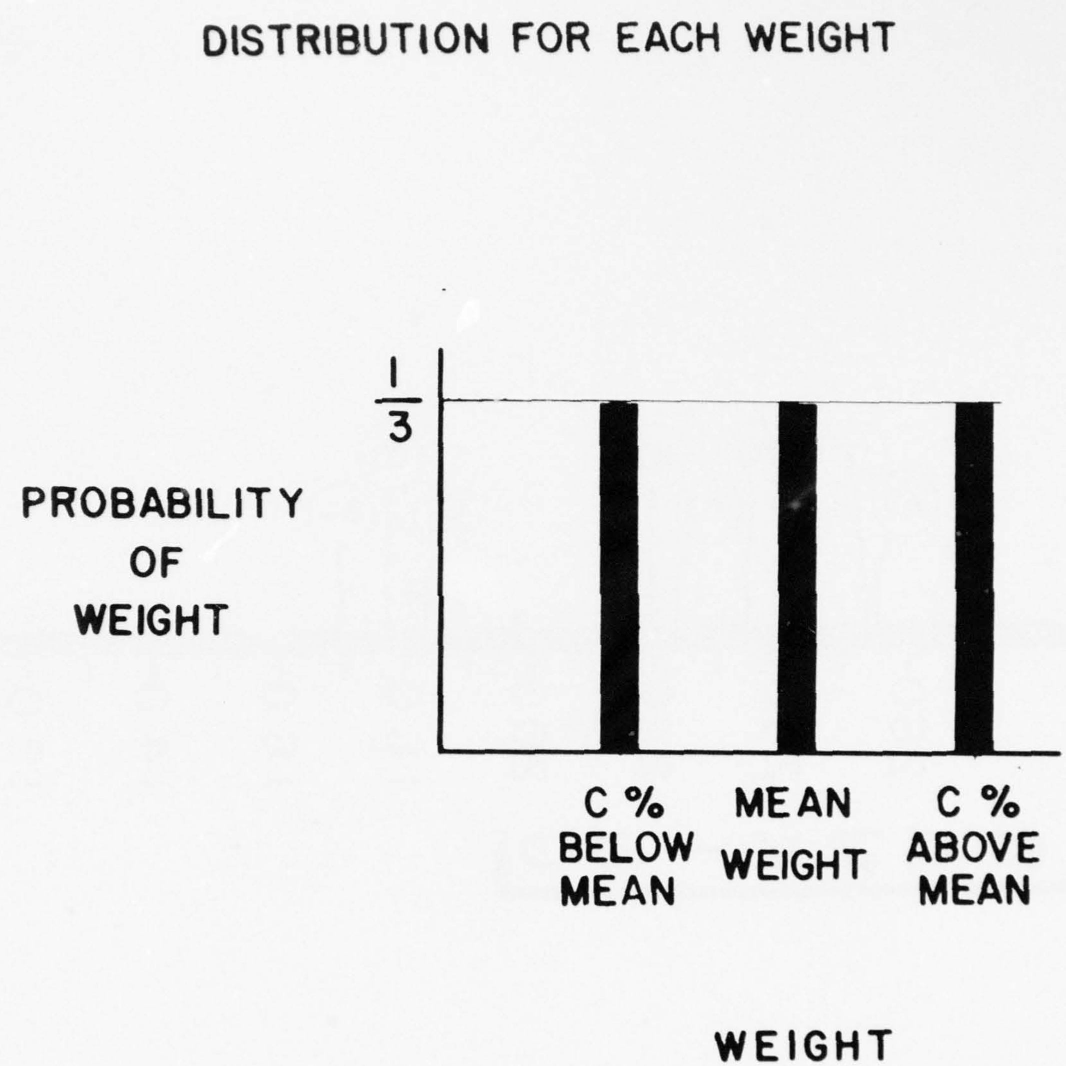

Figure 6. Probability Distribution for Each Weight

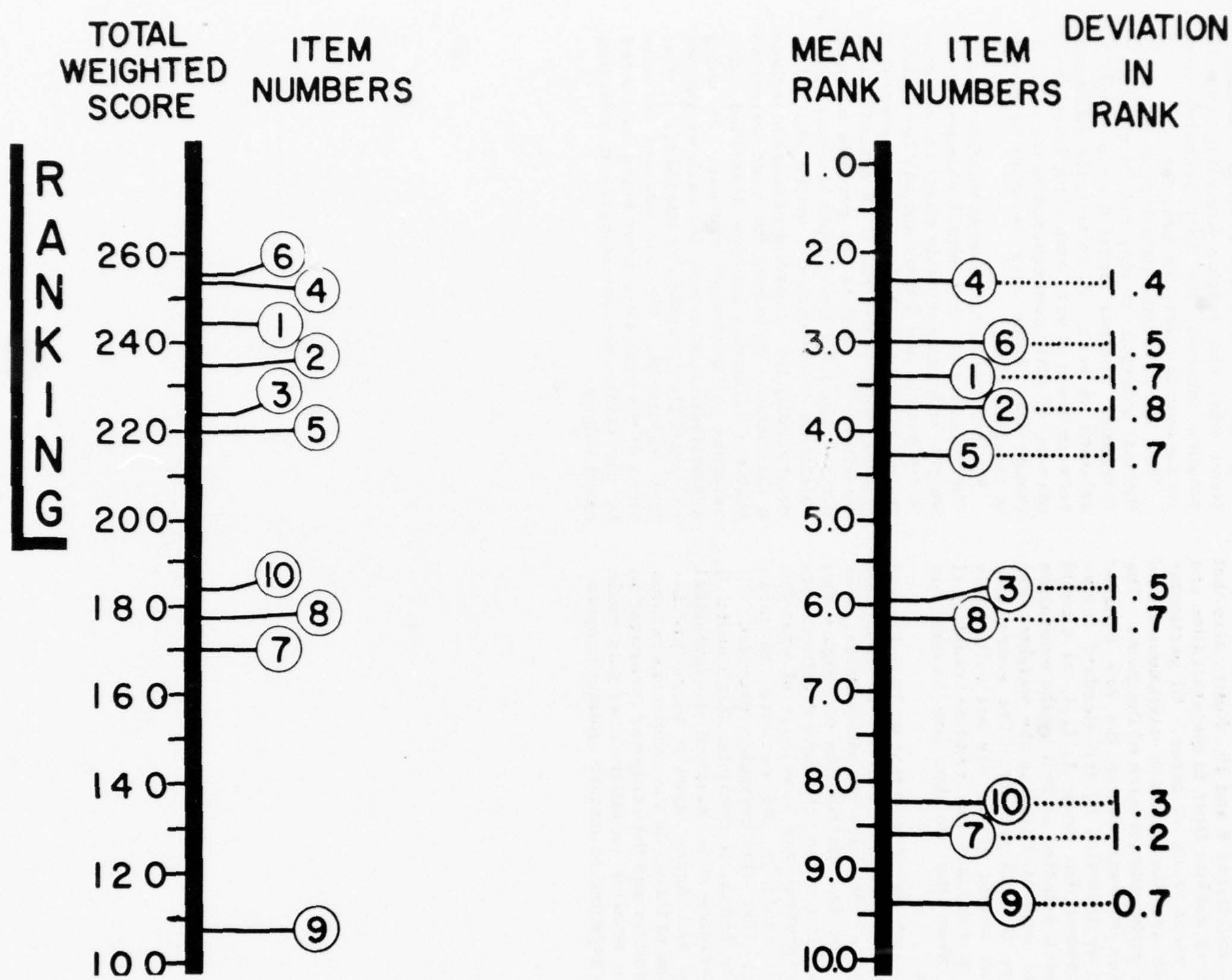

Figure 7. Comparison of Validation Results With the Validation Ranking

trials. Notice that in comparison with the results of the evaluation, items 4 and 6 interchange their positions, as do items 3 and 5, and items 8 and 10. Notice also that item 6 is ranked first in the evaluation and has a mean rank of three. Of particular interest are the standard deviations listed on the right side for each of the items. The variation in rank during the one hundred trials, as indicated by the standard deviations, shows that items 1, 2, 4, or 6 could have been selected as best by the evaluation process without changing the weights used by more than 25 percent. The scored differences among items are not sufficiently large to maintain the relative ranking of items when the weights are varied this amount.

What can we do now that we have learned that our evaluation process is somewhat inadequate? We have two alternatives. If we agree that the distribution of weights that was used in the computer investigation more truly represent our knowledge of what the weights should be, we can use the mean rankings that the computer provided. It would be better, if possible, (but I doubt it) to re-examine the selection of numerical weights and agree upon a more precise definition of them. In the second case evaluation process and the computer investigation with the smaller variation in weights would then be repeated in another attempt to establish validation. If it is still clear that the differences among items are not sufficiently large to maintain the relative ranking of items when the weights are varied over the smaller interval, the only recourse is to toss a coin to select the best one.

With the synthetic data used in this hypothetical example, it may not be possible to determine whether items 4 or 6 should be selected as best. If, in fact, the difference between them is very small, the final choice may be of little consequence to the user although the choice may be quite important to someone else.

We know we cannot assign weights exactly. The assumption that small changes in the weights will not seriously affect the outcome is dangerous and untrue and has been illustrated by example today. In the interest of making good decisions, it is essential that we either (1) validate the process of using single values for the weights by applying the validation procedure, or, better still (2) we must modify the evaluation process to include a distribution of values for each weight so that the validation process described today becomes the evaluation process. By using a distribution of values for each weight, we can properly describe our knowledge of what they should be. We also prevent the outcome of the evaluation from being influenced by our preference for integers in selecting exact values.

IX. SPECIAL PRESENTATION

"THE HUMAN FACTOR ENGINEERING ASPECTS OF MAINTENANCE"
by
Lieutenant Colonel John L. Fellows, Jr., U. S. Army Maintenance Board

Gentlemen, I sincerely appreciate the opportunity to appear before this joint military-industry Human Factors Engineering Conference. It affords me the chance to get in a few words, on behalf of the Office of the Deputy Chief of Staff for Logistics, Department of the Army, concerning the importance of Human Factors engineering for maintainability of Army equipment.

As you well know, our equipment is becoming more and more complex. We agree that this is essential simply because we must be able to compete worldwide in the rapid technological advances of military material. But this same complexity is exacting ever-increasing costs in time, personnel, and material to support the equipment once it is in the field. This we simply cannot afford. So we admit that the equipment itself may have to be complex - but we are convinced that its operation and maintenance does <u>not</u> have to be complex. There is where we expend most of our valuable time, personnel, and material resources in the field - and we must do something to drastically reduce these "costs."

These costs have another effect on operations. This is in connection with "up time" or "down time" of the equipment. Space restrictions placed on the battlefield by the threat of atomic warfare will seriously limit the number of people we can devote to maintenance, and as a result limit the time we can spend to perform maintenance at the organizational level. This means that we must develop the state of the art to meet these restrictions. We cannot tolerate any extra units, or extra people, or extra equipment to perform maintenance, which can be eliminated by adherence to the principles of human factors engineering.

We know that much is being done to apply human factors engineering to improving the operability of military gear - i.e., "The fitting of the operating requirements of the machine to the capabilities of the human who has to operate it." But, we feel that much more can and must be done to apply human factors engineering to improving the maintainability of our equipment - i.e., "Fitting the maintenance requirements of the machine to the capabilities of the human who must maintain it" - especially under combat field conditions.

We realize that essential military requirements must be met, that there are certain overriding considerations which sometimes result in undesirable features and difficult-to-perform maintenance. The major point which I wish to make today is that while we will accept and live with these difficult features, if it is really necessary, we want them subjected to complete and serious review as early and often as feasible so we can be certain that the equipment is as free from maintenance difficulties as we can make it. We want a decision, not a happenstance, to determine the maintenance requirements.

We have inherited some problems from the past which will illustrate what I mean. We are all familiar with the problem in battery connections and the positive and negative poles. The initial designer solved the problem in marking one pole with a plus sign and one pole with a minus sign and making them slightly different in diameter. Time and Murphy's law showed us that it is a relatively easy matter to connect the cables improperly. This new law which I quote is one with which all of us in the maintenance field are extremely familiar: "Anything that can be hooked up wrong, will be." We know the answer to the battery connections. Making one round and one square is a simple solution to this problem; but the cost to convert both the military and civilian economy is prohibitive in this case. If the original designer had recognized this problem and adopted our obvious solution, much trouble in maintenance would have been eliminated.

We want to see the skills and limitations of the individual considered in the design and development of new equipment.

Briefly, and more to the point, we urgently need human factors engineering of our Army equipment of the future to:

a. Improve accessibility for adjustment and minor repair by the operator.

b. Reduce time required to perform this adjustment and repair.

c. Reduce technical skill and manual dexterity required for adjustment, and both minor and major repair.

d. Reduce number of special tools and test equipments needed in the field.

e. Reduce check-out in the forward areas to simple "go-no go" checks with

quick plug-in assembly replacements.

f. Design assemblies and subassemblies to permit economical throw-away of faulty items instead of costly repair.

g. Design for application of automatic test equipment in the rear areas to those expensive assemblies which must be repaired instead of being thrown away.

In short, gentlemen, what I am saying is that early and throughout the development of our complex new material - we must continually apply the very best human factors engineering toward insuring that what comes out of the development and production pipelines can be logistically supported by the average human being who is going to have to live - or die with it in the field. I earnestly solicit your help in this undertaking.

(For a response to Colonel Fellow's requirement, see Chapter X, U. S. Army Human Factors Engineering Committee Presentation, A Matter of Substantive Coordination, Page 71.)

X. U.S. ARMY HUMAN FACTORS ENGINEERING COMMITTEE PRESENTATIONS

1. AHFEC REPORT ON ACTIONS TAKEN SINCE PREVIOUS CONFERENCE, by Dr. Lynn E. Baker, U. S. Army Chief Psychologist, Chairman, Army Human Factors Engineering Conference Committee

As you know, your Conference Committee is established by AR 70-8 to plan and coordinate this Annual Army Human Factors Engineering Conference, and to follow through on recommendations arising therefrom. As has been customary, I shall now report briefly on the most important results of their work during the past year; the present conference; plans for a "circuit seminar series;" the report of the Working Group on Army Fighting Vehicles; and U. S. Army participation in the McGill University Short Course in Human Factors Engineering.

THE CONFERENCE

Since you are all here witnessing directly the results of your Committee's work, I leave it to you to judge the quality of this Fifth Annual Army Human Factors Engineering Conference. Thanks to the AHFEC, it is my own opinion that this has been a most successful conference, and I hope in my summary presentation to comment on measures which the Committee must consider to effect further improvements in future conferences.

All of you here, as well as the HFEC, I'm sure agree that this has been, from the point of view of local arrangements, the finest of these conferences to date. For this we all, with the HFEC, owe our deepest thanks to our host, General Medaris, and to Mr. Cuthill, Chief Engineer of Army Ordnance Command and Colonel Holmes, OACS/R&D, AOMC. With our thanks to these leaders of AOMC we wish especially to express appreciation to Captain Greene and Lieutenant Gallagher, of AOMC's Protocol Office, for the fine facilities and arrangements which they set up for this Conference; to the microphone attendants furnished by the R&D Division of ARGMA; to Miss Lois Williams, our gracious and efficient Secretary; to Mr. Stone, our patient and effective Projectionist; and to Mr. Stone the Manager of the Russell Erskine Hotel, where most of us have been billeted. Finally, our especial thanks go to Mr. Donald I. Graham, who "sparkplugged" these excellent local arrangements which have produced an outstanding Conference. I now ask that you rise and, by your applause, express your thanks to all of these members of General Medaris' AOMC team.

(All rise and applaud)

A MATTER OF SUBSTANTIVE COORDINATION

Colonel Fellows's presentation was especially arranged for this conference because of the expressed desire of DCSLOG that prominent mention be made of the requirement for human factors engineering for ease of maintenance. Since these special arrangements were made, there has come to my attention the report of a study, made under a Signal Corps contract, by the American Institute of Research. The study describes an "Index of Maintainability" which AIR has developed for electronic equipment; and two annexures to the report of the investigation give full "cook-book" instructions for procedures necessary to construction of the index.

I recommend on behalf of this Conference that the Army Maintenance Board and the U. S. Army Electronic Proving Ground at Fort Huachuca give serious consideration to a kind of "user test" of this proposed index. If it is found useful for Army electronic equipments, I am quite confident that similar, though perhaps not mathematically directly comparable, indeces can be developed for other broad classes of Army equipment.

PLANS FOR "CIRCUIT SEMINAR SERIES"

The HFEC, in response to previous recommendations made at these Conferences, during the past year has been making arrangements for a series of human factors engineering seminars modeled after the highly successful series conducted by Dr. Leonard Mead at the Army Chemical Center and reported to this Conference last year. Present plans are that the series will be conducted at:

- Quartermaster Research and Engineering Command, Natick, Mass.
- Army Medical Equipment Laboratory, Fort Totten, N. Y.
- Army Chemical Center, Maryland
- Engineer Research & Development Laboratory, Fort Belvoir, Va.

Transportation Research & Engineering Command, Natick, Mass.
Army Infantry Board, Fort Benning, Ga.
U. S. Army Electronic Proving Ground, Fort Huachuca, Ariz.

While so widely separated a series of stations presents great scheduling difficulties, we hope that a contract can soon be executed which will contemplate the beginning of the series in February 1960, and its completion in April or May of the same year.

REPORT OF WORKING GROUP ON ARMY FIGHTING VEHICLES

In response to a requirement from USCONARC, the HFEC established a special working group to study Human factors problems of sustained operation and occupancy of tanks and fighting vehicles under the conditions of the future nuclear battlefield. The Working Group has finished its report and submitted it to HFEC with the recommendation that it be accepted and the group discharged. I will not summarize the report here for you; it is available for your detailed study if you desire. The report is already obsolete, however, for it has had the immediate effect of generating one new task of research on directly related problems of selection at TAG's Personnel Research Branch, and three new tasks in the work program of the Ordnance HEL.

McGILL UNIVERSITY SHORT COURSE

As coordinated by the AHFEC, some 16 officers have again this year attended the McGill University Human Engineering Institute. In fact, the date for the present conference was selected to permit as many as possible of these officers to attend this meeting at the Institute's close, and many are here. We had planned that Colonel Raymond J. Karpen would present a report to you on his evaluation of this training. Colonel Karpen, however, was somewhat bruised in a motor accident the other day and is therefore unable to be here. He has forwarded his report to Lt. Colonel Paul B. Schuppener who also attended the McGill course and is at this meeting. In the next presentation, Colonel Schuppener will present Colonel Karpen's comments and also his own.

2. COMMENTS ON McGILL UNIVERSITY SHORT COURSE, by Colonel Raymond J. Karpen, Commanding Officer, Army Medical Equipment Laboratory, and Lieutenant Colonel Paul B. Schuppener, Executive Officer

The third course in Human Engineering was held from 9 through 19 September. Twenty students, of whom sixteen were American Army Officers attended the course.

Although it was sponsored by McGill University, it was monitored and arranged by personnel of the Canadian Defence Board who used their summer vacations for this purpose. Dr. C. H. Baker, of the Board, was present during the entire period to give continuity to the program.

The objectives of the course were as follows:

1. The orientation was to deal with practical matters rather than theoretical issues.
2. The primary objective was to develop a point of view, not to pass on specific data.
3. Sources of specific data were identified.

Instruction was by means of lectures and by group discussion. In the latter, the discussion leader carried the thread of the subject and the students participated by raising questions or by recounting experiences of their own that added to the general knowledge.

At the onset, it was pointed out that human engineering is not necessarily applied common sense as some have defined it. Dr. Baker's concept is that "the duty of a human engineer is to assist in the design and development of equipment so that it may be used and maintained with maximum efficiency, with minimum selection of operators and maintainers."

Because of the strong experimental psychological orientation of the course and because a major part of human engineering involves human behavior, a certain common psychological background was assumed by all of the discussion leaders. This was brought out in a discussion of the process of learning including progress, motivation, overlearning, economy in learning and forgetting.

The physiology of the eyes and ears was discussed in detail to enable the student to realize the advantages and limitations of these organs to be considered in the design of visual and audio displays.

Visual acuity was discussed along with the effects of such factors as background brightness, contrast, motion, visibility, color and flicker.

It was brought out that man has some fourteen senses rather than the six usually attributed to him. Among others are the senses of vibration, pressure, kinesthesis, position and movement and cutaneous pain.

Dr. Mackworth led the discussion on the subjects of decision taking, effect of environmental stress on the performance of personnel, effect of aging and the loss of sleep. With regard to heat, the fall of efficiency was observed to be continuous over a two hour test. Heat also reduced accuracy and increased secondary corrective movements in a tracking test. The loss of one night's sleep in one

test led to the deterioration in the performance of a long simple task in which the nature of a signal was known but not the time of its arrival. As to the effect of age, older people are slower due to slower mental processes, not to slower muscular activity. Less information can be dealt with in a given time. As compensation for this, they try to arrange movements ahead and therefore react poorly to unexpected events.

Dr. Mackworth discussed his recently developed technique for following eye movements of subject performing a task. By means of a dual television hookup, he superimposes a reflection of the eye movements on the picture of the task being performed. As an example, he projected a motion picture of a subject playing checkers. The eye movement superimposed on the checker board showed the subject considering the various moves. As a matter of fact, it gave one the impression that he was peering into the subject's brain.

A recent development in the field of electroluminescence was demonstrated. Use is made of a phosphor that emits light when exposed to a direct electrical excitation by an alternating current. Colored electroluminescent panels may be fabricated. Possible human engineering uses include instrument dials, control panels, highway signs or in any situation where a dim light must be provided.

One session dealt with the design of instrument displays. Design features included the use of black dials on white for short reading times; when possible placing scale numbers outside the scale rather than inside to avoid obscuring the scale by the pointer; using common objects of reference as increasing scale numbers in a clockwise fashion; reading from left to right; using linear scales and the same direction pointer orientation for groups of dials.

Dr. Neely of the Defence Research Board presented a discussion on the effect of noises. He pointed out that exposures to high intensity noise may change hearing acuity, change efficiency of transmission and reception of voice communications, cause mechanical or pathological damage to the body and change efficiency in which a man can perform skilled and unskilled tasks. A noise of 130 decibels is a painful sound. Workers when exposed to noise levels of 85 decibels or more for prolonged periods should wear ear plugs or ear muffs. In addition to protecting the hearing, they enable the wearer to hear conversation better in a noisy environment.

Dr. Baker covered the subject of control forces as they apply to human muscles. He made observations that left hand strengths are consistently about ten percent lower than right hand strengths; push and pull values are greatest when the arm is extended 180° or 150°; up and down forces are greatest when the arm is down near to the side 120° or 90°. These data are applied to human engineering considerations in the design of foot pedals, hand levers and door handles. Back lifts varied from 330 to 800 pounds for a group of USAF students. Leg lifts varied from 700 to 2500 pounds with a median of 1482 pounds.

He then covered the matter of control knobs. The data that he presented indicated that tapered knobs result in larger discrepancies (16°) as compared with 1.4° using bar type knobs between right and left hand operation. Settings with a tapered knob are more counterclockwise with the left hand - more clockwise with the right than are those with a bar type knob. The right hand bar type knob gave the greatest accuracy.

Dr. Chapanis discussed the field of operations research and then demonstrated a simplified mathematical procedure for solving problems of assignment. As an example, one problem involved basing of flight crews and pairing up flights to result in a minimum layover time for crews in the distant city. This consideration involved ten flights or a possible 3840 solutions. With the simplified methods, the problem was solved in a relatively short time by a method of matrices.

Professor Ham of the University of Toronto devoted a day to the discussion of control systems with the human operator in the control loop. He demonstrated a block diagram method for analysis of man-machine systems. These considerations have great significance in the field of automation when considering the reliability of the human link.

Consideration was given to the problem of design for ease of maintenance. In this regard, reliability was defined as, "The probability that a component will function through its required life span." Some of the precepts developed were: simplify system function and design; where possible replace electronic tubes with other components as transistors, selenium rectifiers, and magnetic techniques; design first for reliability and secondly for maximum performance; observe the component limitation specified by the manufacturer and avoid the use of non-standard items. With regard to personnel, written tests are not the best way to evaluate maintenance men. Also, maintenance records have been shown to be poor in rating efficiency. Improving of training or performance in the maintenance area has been accomplished by the use of visual training aids such as "Diagnostigrams." These lead the electronic student through a circuit which has all of the electronics values shown at various points and reasons therefor.

The importance of the use of mock-ups for design economy was stressed. By means of corrugated cardboard, plywood, chicken wire and other inexpensive materials, mock-ups can be fabricated. They are so constructed that only essential shapes, functions and effects are represented. These same

considerations were extended to the use of three dimensional models in designing warehouse lay-outs. Using scale model walls, pillars, racks and conveyors, it is convenient to work out an optimum layout at little expense.

The foregoing comments cover some of the highlights of particular interest to me. I'm sure that others would have selected other items. Our group represented various interests and different backgrounds and no doubt each person had his own expectations as to the information he wanted to obtain.

In my opinion, the course was excellent in all respects. In addition to newly acquired knowledge, each student was furnished detailed outlines of all of the subjects discussed along with bibliographies of source materials. I believe that there should be continued participation in the course and that personnel concerned with the field of Human Engineering be given the opportunity to attend it.

LT. COLONEL PAUL B. SCHUPPENER

I am in complete agreement with the foregoing remarks prepared by Colonel Karpen. However, I would like to add a few personal observations and recommendations:

I believe a more appropriate emphasis on the course content can be obtained by calling it "Engineering Psychology" rather than "Human Engineering."

I would limit attendance to those with engineering degrees and a broad background of research and development or training experience. These prerequisites should make it easier for the Institute Director to establish a properly balanced course devoid of unnecessary repetition and yet with proper explanation of new or unfamiliar concepts.

I would place great emphasis on the theme that out of the laboratory data compiled by psycho-physiologists has come and will come information of great practical value to the design and maintenance engineers. I commend the course instructors for making it clear from the onset that ultimate responsibility remains with the design engineer.

I would strongly support a doctrine advocating the establishment and/or strengthening of laboratories designed to furnish practical research data in handbook form to the responsible design engineers. I would stress as an additional valuable contribution of laboratories so constituted the capability to provide fresh, constructive criticism of proposed designs.

3. CONFERENCE SUMMARY AND HIGHLIGHTS, by Lynn E. Baker, U. S. Army Chief Psychologist, General Conference Chairman

Combat Mission as a Psychological Design Parameter

The theme of this Fifth Annual Army Human Factors Engineering Conference has been "Man and Firepower." In harking back, in summary, to this theme I remind you once again that we deal with the theme from a uniquely Army point of view. For us it is more precisely stated: "Man and Firepower for the Army's Combat Mission." You may feel entitled to prefer its briefer, three-word, statement on the grounds that the qualifying phrase "for the Army's Combat Mission" is obvious.

But this qualification may not always be so obvious. It may deserve repetition.

Last year, in his greetings to the Fourth Annual Conference, General Trudeau took occasion to remind you that: "In the Army, the soldier is typically not in a ship which is in battle; he is not in an aircraft which is in battle; he is himself in battle directly, immediately, personally -- a tactical entity of combat power." This year he has again stressed this concept in his keynote speech to this Conference. In stressing this notion General Trudeau has performed a most useful service for us as psychologists and as design engineers: he has succinctly differentiated the context in which will occur the human activities which we study. Long before William James said it, psychologists knew that it is different if I step on your toe, then apologize; than if I apologize, then step on your toe. General Trudeau knows that William James knew: that understanding the context in which a human act occurs is important to an understanding of the act itself.

I belabor this point because in the past year and a half I have accumulated a few informal data which suggest that some psychologists outside the Army may not yet fully understand this important consideration. Specifically, since the middle of August 1958, I have taken occasion to interview 36 psychologists on the matter of the implicit specifications of their "image" of a "missile." These interviews always occurred informally over a cocktail or in a streetcorner conversation much like many conversations which occur now-a-days in American living-rooms. The interview situations had the following uniform characteristics:

a. the conversation was always a private, two-person conversation between me and the Respondent.

b. In all 36 cases Respondent was a psychologist, PhD level, known by me not to be employed by the Army either directly or on contract -- in short, not one of you, but such a person as you might be pleased to consider for employment in your program.

c. In all 36 conversations, the subject of human factors in missiles and missilery was first broached by the Respondent, not by me.

In such an informal situation, when the subject of missiles was broached, I would introduce substantially the following critical test-question:

"Well now, what do you mean when you speak of a missile? After all, a musket-ball in the American revolution was a missile, and so is an Australian bushman's boomerang."

The results were as follows:

a. In only one case did a Respondent answer the critical test-question by indicating any awareness of the existence of a wide gamut of different families of missiles designed for a wide gamut of different tactical uses. This one Respondent replied substantially as follows: "I see the point of your question; there must be enormous differences in the operator behaviors demanded by a mobile anti-tank weapon, for example, as compared with a large intercontinental missile."

b. In all other cases Respondent's reply to the critical test-question indicated that, while he thought he was speaking of missiles in general, his "image of a typical missile," really considered only: (i) extremely long-range missiles, (ii) fired from fixed or "hardened" sites.

I am not necessarily concerned here with the erroneous public stereotype which focuses only on the glamorous hardware which promotes justifiable hopes of interstellar flight and unjustifiable delusions of push-button warfare.

I am concerned with the fact, that, in A.D. 1958 and 1959 there may be as many as 35 otherwise qualified psychologists who give no indication of realizing the psychological importance to design of the combat mission for which a weapon will be used. I conclude, in view of the emphasis placed on this matter by General Trudeau, that you will want to take appropriate action to orient all new professional recruits in this matter as a routine part of their introduction to our work.

This emphasis on the combat mission as a major psychological parameter of design seems to me to be a most important highlight of this conference.

Creative Role of USCONARC in Design

A second point that becomes increasingly clear to all of us as these Annual Conferences pass in review relates to the manner in which the "user agency" influences design decisions.

We humans tend to think and instruct each other in terms of parables and analogs. We note that USCONARC, in laying down the Military Characteristics (MCs) for a weapon is establishing the "ground rules" for our design. We further note that USCONARC, in the so-called "user test" judges the results. The analogy seems straightforward, simple, and complete: USCONARC's role is the role of an umpire.

When we examine all of the relevant facts, however, we are forced to reject our simple little analogy as attractive but invalid: USCONARC is not the umpire, USCONARC is a member of the design team. USCONARC's role is not a passive and aloof role, limited merely to laying out the ground rules then judging the results. This may be a conceivable, though not ideal, limitation in the purely hardware case. In the case of human factors it is a limitation which cannot be tolerated. Whatever may be true for hardware in itself, human factors in design cannot be effectively taken into account without full closure of the feed-back loop from the user test. This feed-back is a necessary, though not sufficient, determiner of human factors in design.

It has been a high-light of this conference that it has made increasingly clear the creative role of USCONARC as respects human factors in the R&D process. I recommend that we find all possible means to assist USCONARC in this vital process.

Feed-Forward Loops to Selection, Training and Industry

Dr. Richard Weiss, ARO's Chief Scientist, comes from a Signal Corps background. He frequently finds it useful to describe the R&D process in terms of regenerative circuitry, as we have just done to emphasize USCONARC's role. To continue our use of Dr. Weiss' device, it may now be useful to consider some further loops of our communications circuitry.

After five years of these Annual Conferences, and especially since the creation by Army Regulation of your Human Factors Engineering Committee, human factors engineering has earned an accepted, recognized, place in the total Army R&D effort. I call your attention to the fact that we no longer need to spend our efforts in these Conferences and elsewhere defining human factors engineering and explaining what it is. We know what it is, the Army knows what it is; you have become an identifiable participating professional community in the Army's R&D domain.

I wonder now at this Fifth Annual Conference if the time has not come to look a bit farther than yourselves. General Trudeau mentioned it twice:

(a) As Army Human Factors Engineers, what is your proper relation to the industrial community? Is this Conference, which must certainly remain an Army conference, both giving and receiving an adequate exchange of information with our colleagues in industry?

(b) What is your proper relation to the rest of the Army's human factors R&D program? What information should you give to, and what should you receive from, the work of TAG's Personnel Research Branch on selection, classification, and utilization. Similarly, what communications loops should exist between you and HumRRO's research and development of Army training? Ditto for the Army's participation in the Naval Training Device Center.

If nothing else had done it, I'm certain that General Trudeau's mention of these matters would cause you to give them your most earnest consideration. It may well be that the time has come to change these conferences from "Annual Army Human Factors Engineering" conferences, to "Annual Army Human Factors R&D" conferences. In any case, I am sure that you will wish in future to invite a much fuller participation by our colleagues in industry.

General Trudeau's injunction to widen your horizons, to consider further feed-forward loops both within and outside the Army, appears to me to be a third major highlight of this conference.

Each of the papers presented at this Conference has been useful and worthy of your attention here and from time to time in future; to mention one would necessitate mentioning all. To express gratification on La Rue's paper on mock-ups, which I'm sure will often be useful to all of us in future, would require also that the same be done for Fletcher's acoustic reflex paper, for which I am also sure there will be many future uses of a different sort. In short, each paper was itself a highlight if one simply looks at the Conference from a different angle.

Aside from these substantive accomplishments, as well as many others which could have been presented with no limitations of time and theme, you are entitled to be pleased at a number of improvements which you have made and can in future make in the organization and resources for Army human factors engineering; and I am sure that you look to the Army Human Factors Engineering Committee for guidance and recommendations to further improvements.

There being no further business at this time, I declare this Conference now adjourned at 1030 hours on 24 September 1959.

APPENDIX I

ROSTER OF CONFEREES

ABRAHAM, Jeff D.	Sig. Comm. Dept., USAEPG Fort Huachuca, Arizona
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APPLEWHITE, K. H., Major	USAOMC, Redstone Arsenal, Alabama
ASHLEY, Houston Willard	USAOMC, Redstone Arsenal, Alabama
ASHLEY, Merle W., Captain	USAOMC, Redstone Arsenal, Alabama
ASKIN, David	Frankford Arsenal Philadelphia, Pennsylvania
ATKINS, Emory L.	USAOMC, Redstone Arsenal, Alabama
AXELROD, Irving	Republic Aviation, New York
BAILEY, Dr. John W.	USA TRECOM, Fort Eustis, Virginia
BAKER, Dr. Chester H.	Defence Research Board of Canada
BAKER, Dr. Lynn E.	USA Chief Psychologist, OCRD, DA Washington, D. C.
BARBER, Jacob L., Jr.	USAERDL, Fort Belvoir, Virginia
BARNARD, Lyle Martin	USAOMC, Redstone Arsenal, Alabama
BAYELIE, G. J., Jr., Lt. Col.	OCRD, DA, Washington, D. C.
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BEMIS, Wilber G., Lieutenant	USAOMC, Redstone Arsenal, Alabama
BETHAY, Joseph Arwoot	USAOMC, Redstone Arsenal, Alabama
BIRRER, Dr. Ivan J.	USA Command and General Staff College Fort Leavenworth, Kansas
BLACK, J. W.	Army Development Establishment Army Headquarters, Canada
BOWMAN, Jerry D.	USAOMC, Redstone Arsenal, Alabama
BUNN, Frank C.	USAOMC, Redstone Arsenal, Alabama
BURKHALTER, T. H., Captain	QM R&E Command, Natick, Massachusetts
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CAUGHEY, John H., Colonel	ODCSPER, DA, Washington, D. C.
CHAMBERS, John	USAOMC, Redstone Arsenal, Alabama
CHASTEEN, Paul C., Captain	USAOMC, Redstone Arsenal, Alabama
CHESSNOE, Michael, Lt. Col.	USAOMC, Redstone Arsenal, Alabama
CLANTON, Henry M., Lt. Col.	USAOMC, Redstone Arsenal, Alabama
CLEFT, J. B., Major	USAOMC, Redstone Arsenal, Alabama
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CONNER, Lloyd W.	USAOMC, Redstone Arsenal, Alabama
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CUTHILL, S. W., Colonel	USAOMC, Redstone Arsenal, Alabama
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DeFEDE, Edward P.	Martin Company, Orlando, Florida
DeTOGNI, Gino R.	Watervliet Arsenal, New York
DIHM, Henry	USAOMC, Redstone Arsenal, Alabama
DOBBS, Stephen John	USAOMC, Redstone Arsenal, Alabama
DOOLEY, E. M., Lt. Col.	USAOMC, Redstone Arsenal, Alabama
DUERR, Fredrick	USAOMC, Redstone Arsenal, Alabama
DUSEK, Dr. Edwin R.	QM R&E Command, Natick, Massachusetts
ECKENRODE, Robert T.	Dunlap and Associates, Incorporation Stamford, Connecticut
EDMONDSON, Earl R.	USAOMC, Redstone Arsenal, Alabama
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ELY, William J., Brig. Gen.	OCRD, DA, Washington, D. C.
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FLETCHER, John L., Captain	Fifth Army Headquarters, Chicago
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FYE, Richard S., Captain	USAAMS, Fort Sill, Oklahoma
GALLAGHER, Hugh P., 1st Lt.	USAOMC, Redstone Arsenal, Alabama
GARDNER, Earl B.	Convair, Pomona, California
GEARAN, William K., Captain	USA Aviation Board, Fort Rucker, Alabama
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GILBANKS, William R., Captain (OGMS)	USAOMC, Redstone Arsenal, Alabama
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HERBERT, Morris J., Captain	USAOMC, Redstone Arsenal, Alabama
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HOOPER, Albert W.	USAOMC, Redstone Arsenal, Alabama
HOWELL, Cleves	USAOMC, Redstone Arsenal, Alabama

HOYT, Dr. Ruth	Defence Research Board of Canada
HUETER, Hans	USAOMC, Redstone Arsenal, Alabama
HUGHES, James	USAOMC, Redstone Arsenal, Alabama
HUGHES, Thomas D.	Watertown Arsenal, Massachusetts
HUNT, William A.	Northwestern University Evanston, Illinois, and ASAP, OCRD
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JOHNSON, William A.	Rock Island Arsenal, Illinois
JONES, Nelson H., Captain	Army Chemical Center, Maryland
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KAPPEL, Carl W.	Fort Bragg, North Carolina
KARR, Charles A.	Frankford Arsenal, Philadelphia, Pennsylvania
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WHITLEG, Robert	USAOMC, Redstone Arsenal, Alabama
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WILLING, W. R., Captain	Canadian Liaison Office, ARGMA
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WOODS, Dr. Irving A.	USA Ordnance Human Engineering Laboratory Aberdeen Proving Ground
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ZEIDNER, Joseph	TAGO, DA, Washington, D. C.

APPENDIX II

U. S CHEMICAL CORPS
CURRENT WORK PROGRAM AND BIBLIOGRAPHY IN HUMAN FACTORS ENGINEERING

U.S. ARMY CHEMICAL WARFARE LABORATORIES, ARMY CHEMICAL CENTER, MARYLAND

A. CURRENT WORK PROGRAM

1. E41 Field Alarm

The E-41 Model Point Source Alarm is currently being developed. It has been designed to replace the standard E-21 model. The E-21 is capable of automatic operation for a period of twenty-four hours. It is necessary, however, that a relatively complex series of tasks be performed in the field in order to prepare this alarm for automatic operation. Design, written instructions, and operating procedures have been evaluated and modified as a result of a series of laboratory tests. A second series of tests will include field use of the alarm system.

2. Psychopharmacological Studies

At present, the operant laboratory is engaged in research aimed at uncovering some of the effects of drugs which have the locus of action in the central nervous system. This research involves two major phases:

a. the investigation of behavioral problems in order to understand, with a sufficient degree of sophistication, undrugged behavior,

b. the investigation of the effects of drugs on previously known baseline behaviors. Additional psychopharmacological studies, using human subjects, are investigating the effects of these agents upon personality changes as measured by interviews, projective tests, and objective tests. A second group of investigations will attempt to determine the effects of the administration of these agents upon performance in a series of vigilance tasks.

3. Field Decontamination Kit

A kit has been developed for the purpose of personal decontamination in the field by persons exposed to lethal chemical agents. This kit is being evaluated in terms of time required to learn to use it, actual use time, adequacy of printed instructions, and special difficulties related to its use.

4. Effects of Military Chemicals on Operational Tasks

Among current investigations a major project has the purpose of predicting the effects of incapacitating agents upon the operation of complex military equipment. Toward this purpose a series of laboratory tests is being selected, both from among existing standardized tests and from measurement techniques now being developed at the Army Chemical Center. A second approach involves field tests during which standard and candidate chemical agents are administered to persons actually using operational equipment or, in some instances, corresponding simulators. We are especially interested in the effects of these agents upon command and decision functions and upon communications among persons engaged in the operation of fire control systems.

5. Kit, Conversion Medium G. P. Tent, Protective Shelter, E21

Tests are being conducted on a third prototype of this shelter which has been modified to enhance the habitability of the shelter during summer weather. Body temperature and heart rate measurements on human occupants are used to monitor heat stress during occupancy. The area of diffusion filter material has been increased in the new prototype in order

to increase the outward transport of water vapor exhaled by the occupants. A radiant heat filter has been incorporated into the shelter ceiling to reduce solar heat load. These modifications have reduced the heat stress on occupants of the shelter during summer weather.

6. Mask, Gas, Rocket Propellant, E15

Tests are being undertaken on this mask to determine its compatibility with Quartermaster Corps protective clothing when worn by human subjects during exercise.

7. "Repellent" Underwear Fabrics

Tests are currently under way on experimental protective underwear (permeable) made of repellent treated fabric. The heat stress of exercising human subjects wearing this underwear under impregnated outer protective garments (permeable) is being compared with that of the same subjects wearing the standard two layer impregnated protective costume.

8. Use of Diffusion Material in an Underground Shelter

Preliminary tests have been carried out in which human subjects occupied a dugout converted by use of diffusion felt into a field protective shelter. In this kind of shelter the occupants were subject to less heat stress than is encountered in above ground protective diffusion shelters during comparable summer weather conditions. Presumably the capacity of the ground to act as a heat sink is largely responsible for this result.

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APPENDIX III

U. S. ARMY MEDICAL SERVICE
CURRENT WORK PROGRAM AND BIBLIOGRAPHY IN PSYCHOPHYSIOLOGY

A. CURRENT WORK PROGRAM

Task I - Investigation of Sound and Hearing in Relation to Performance

a. U. S. ARMY MEDICAL RESEARCH LABORATORY

These studies historically have aimed at determining levels and spectra of military noise environments and their effects on audition and on performance, as well as basic studies in audition. Further data in the study of the effects of noise exposure were collected early in the year. Because of the absence of the primary investigator during the coming year, such work will be kept at a minimum.

A complete study (US AMRL Report No. 384) was concerned with localization of sound, stressing the importance of learning in judging distances of sound sources from the observer. It was shown that increasing familiarity with the actual frequency and loudness characteristics of the sound was important in reducing errors of judgment.

An investigation into the phenomenon of aural overload as a predictor of hearing loss showed generally negative results and was discontinued.

The bulk of research during the year has been in investigating various aspects of the acoustic reflex. Reports are in various stages of preparation but have not been published. Knowing that intense noises activate the contraction of the tensor tympani and the stapedius muscles, thus attenuating sound energy conduction, researchers attempted to utilize this reflex as protection against the sudden and intense impulse noise of the firing of large guns. A delay of several milliseconds is introduced into the electric firing mechanism of the gun. During this delay, a noise of 100 decibels is fed into the ear, activating the reflex immediately prior to the firing of the gun. Considerable protection has been demonstrated. Further studies are concerned with the comparison of attenuation provided by ear plugs and by the reflex, and with determining threshold shift and changes in perception of loudness as a function of loudness of stimulus noise. Studies on animals are concerned with the measurement of cochlear microphonics in ears with and without the stapedius tendon sectioned, providing indices of decrement in treated and untreated ears when exposed to noise with and without acoustic reflex protection.

A separate project is aimed at studying the generalization characteristics of frequency of tone as a function of training along a different dimension, namely, intensity.

b. Contract Studies

Measurements have been made of the noises associated with the firing of an M-1 rifle, 30 caliber and 50 caliber machine guns, a 76 mm gun, a 90 mm gun and a 105 mm howitzer. Characteristics of the noises were described in terms of maximum instantaneous peak value, the duration, the rise time, and the frequency spectrum. The distribution of these parameters in and around the several weapons has also been investigated. Recommendations were made concerning efficient data recording techniques. Attempts will be made to relate these measured characteristics of Army weapon noises with hearing loss data.

Comparison has been made of recording techniques for the function of the inner ear using round-window electrodes, single electrodes and paired differential electrodes. It was shown that a round-window electrode records from the entire cochlea and when properly interpreted gives adequate information without the necessity of drilling holes in the cochlea as with differential electrodes. It was also shown that the so-called "sharpening process"

does not occur through any precise pattern on the basilar membrane nor specifically in the nerve, but probably through some mechanism by means of which the diffuse nerve endings "interpret" the action along the extent of organ of Corti.

Descriptions were made of the effects of a test tone on an injured ear, the necessity for sweep-amplitude measurements, and the injury recovery cycle in the organ of Corti. Histological studies showed the acoustic ganglion to arise from the auditory vesicle, not the neural crest.

A new study will be initiated focussing on the effects of practice on sensory discrimination in order to determine whether thresholds for high or low frequency tones are changed depending on various controlled factors.

Task II - Investigation of Vision and Perception in Relation to Performance

a. U. S. ARMY MEDICAL RESEARCH LABORATORY

This work continues at the task of analyzing and specifying the relationship between physiological optics, psychological variables and visual perception. Historically, the original work of this branch was concerned with depth perception and optical aids. Emphasis has moved toward other more basic variables in perception and vision. A series of studies related to the perception of depth, space and shape have been completed.

Testing the previously developed hypothesis that the perceived size of width or height of frontal extents in the vicinity of a binocular disparity determines the perceived depth associated with the binocular disparity, two experiments were conducted. Frontal size judgments and depth judgments were obtained. The results support the notion that frontal extent is an important determiner of perceived depth.

Three experiments were directed at investigating the effects of convergence and angular size upon the observer constant noted in previous work. Equations were derived for calculating this constant under different amounts of frontal size constancy.

In two experiments, binocular disparity was used as the dominant determiner of the perceived depth. Under these conditions (1) an assumption of perceived absolute distance was not necessary to explain three-dimensional shape judgments, (2) the physical depth interval required to perceptually duplicate a constant frontal size in depth increased as the distance of the object increased, and (3) the observer constant was found useful in predicting shape judgments.

Theoretical formulations expressing the various relationships mentioned above have been further developed during the year.

Work in physiological optics continued with emphasis on empty field conditions. Presently, interest is centered in the relation of cyclotorsional movement of the eyes to the perception of slope. Indications are that the resting position of the eyes accentuates the perceived slope of an object tilted toward and diminishes the perceived slope of an object tilted away from the observer. Present research is aimed at determining the role of cyclotersional changes in bringing about this phenomenon. This program will continue to work out the interrelations of physiological, psychological and other perceptual factors.

b. Contract Studies

Three major problems concerned with the perception of objects in a uniform visual field similar to the Greenland "White-out" were investigated. These were (1) the extent to which the accuracy of form recognition is dependent upon the structure of the visual field, the structure of the target, and prolonged exposure (90 sec) to a uniform visual field; (2) the dependence of spatial orientation on field structure, characteristics of the target, and the subject's set; (3) the effects of prolonged exposure (20 min) to the uniform visual field which involved temporary cessation of vision. Both uniformity and prolonged exposure reduced the accuracy of recognition, but their influence varied with target complexity. Sensitivity to change in tilt was shown to be dependent on the three variables studied and an interaction effect was noted. More frequent and more intensive "blanking out" was reported on longer exposure to uniform white stimulation.

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ROTC students have received training in night-vision followed by two hours of testing on a night visual task. Continuous performance records were registered to determine the characteristic patterns of fluctuation.

A series of studies has centered around the temporal factors in visual perception. A survey of methods for recording and analyzing evoked potentials in human subjects was made and a satisfactory inexpensive procedure settled upon. This involves making a large number of oscillograms and plotting the results algebraically. Devices have been constructed for electronic control of brief light sources and light/dark ratios with variable durations, intensities and frequencies. Identical controls for stimulating the eyes separately or in combination have also been developed. A variety of studies will be undertaken on perceptual blanking and perception time; bilateral in-and out-of-phase fusion; critical flicker fusion; brightness enhancement; photic driving; etc.

Experiments have been conducted recording single unit potentials with microelectrodes in animal retinas. Techniques for isolating and identifying single unit responses have been described. Responses were recorded under dark adapted and light adapted conditions for the single unit responses to stimuli of varying wavelength. Other experiments have explored the effectiveness of very small spots of monochromatic light on the human eye. These experiments involve the measurement of the increment thresholds for monochromatic light and the calculation of the spectral sensitivity curves for repeated stimulation of the same retinal area. One curve tentatively identified has been shown to be similar to the ICI photopic luminosity curve; another shows increased sensitivity to red radiations.

Task III - Improvements of Control and Coordination in Performance

a. U. S. ARMY MEDICAL RESEARCH LABORATORY

Historically, psychomotor studies at this laboratory were concerned with tracking performance under various conditions of stress and environment. In the past two years, the emphasis has changed markedly toward research in fatigue, skill decrement and the role of biomechanics in performance.

The driver fatigue studies promised in previous reports have begun. Underestimation of the magnitude of the task of constructing the test course along with some shortage of help in construction delayed completion of the course until late in the fiscal year. Subjects are put through long fatigue sessions of vehicle driving accompanied by and terminating in a variety of tests of decrement in the complex skill of driving.

Studies in biomechanics continue. A completed investigation gives information on the effects of elbow angle and back-rest height on the strength of hand movements. With a back support, pushing force was greatest with an elbow angle of 135° or 160°, i.e., just prior to complete straightening of the arm. Back-rest height was shown to be most contributory to strength of push at 60% of the seat to shoulder distance.

Another study is an analysis of the effects of elevation, lateral position and distance of hand control on the strength of six linear hand movements. Equations derived from these data may be used to determine optimal locations of hand controls, or used to determine the characteristics of controls with a predetermined position.

Analyses of fatigue and of body mechanics will continue as prime areas of research.

b. Contract Studies

A series of studies concerned with certain physiological correlates of psychomotor functioning showed that (1) under certain conditions sleep deprivation could bring about hallucinatory phenomena (2) mild electric stimulation had a differential effect under different conditions for learning, - (higher or lower activation levels may be required depending on the conditions) and (3) continuous amplitude/time analyzers applied to EEG during sleep yielded smooth falling curves similar to those obtained from certain peripheral physiological functions.

In a study concerning context effects in psychophysical judgments a review of the literature has been made; apparatus evaluation has been completed; and preliminary testing of subjects has begun. Data on weight discrimination and duration discrimination using an

"up-and-down" psychophysical method have been collected. So far, the time error for weight seems to be independent of whether two judgments are made with one hand, or one with the one hand and a second judgment with the other. This argues against the error being due to transient fatigue.

Task IV - Investigation of Motion and Balance in Relation to Performance

a. U. S. ARMY MEDICAL RESEARCH LABORATORY

Studies in this area are aimed at developing an understanding of the vestibular system and its interactions with other sensory systems and motor systems of the body.

The work of the past year can be divided into four areas:

(1) Experiments on humans using simple stimuli in which relationships between the stimulus, the theoretical response of the sensory organ and the recorded response of the subjects are examined. Responses recorded have been the time characteristics of the experience of rotation, estimates of subjective angular displacement, and nystagmic eye movements.

(2) Experiments on human subjects with complex stimuli involving simultaneous stimulation of the vertical and horizontal canal systems and the otolith organs. An attempt has been made to quantify certain aspects of the subjective responses and to relate these to some aspects of the complex stimuli which were varied systematically.

(3) Electrophysiological experiments on neural activity in the brain stem of cats (acute preparation). Electrical stimulation of labyrinthine structures was accomplished by attaching electrodes to the round window of both ears and recording electrodes were placed in the region of the right medial vestibular nucleus.

(4) Chronic preparations of cats involving the use of implanted electrodes have been used to study simultaneously eye movements, EEG, and neural activity of the brain stem. This technique promises to be useful in the study of quantitative relationships between the stimulus and a variety of aspects of the vestibular reaction before and after surgical modification of the central nervous system.

The greater part of the work accomplished has been directed toward clarification of vestibular peripheral and central nervous system mechanisms mediating the responses to angular acceleration. Such work will continue to be of prime interest.

b. Contract Studies:

None

Task V - Studies of Complex Behavioral Processes in Performance

a. U. S. ARMY MEDICAL RESEARCH LABORATORY

A large primate colony has been built up with facilities for adequate care and for experimental testing of the animals. Two long-range projects have been concerned with complex learning and discrimination learning. Other joint projects with other divisions are under way or planned as means of determining the results of certain traumatic procedures. A report has been made surveying primate behaviors and capabilities.

Recently started is a project wherein the effects of limbic system ablations (electrolytic) on emotional behavior in the rat are being investigated. Recent research has suggested that pyriform cortex ablations lead to an increase in emotional behavior as indicated by a modification of the Brady-Nauta indices such as resistance to handling and vocalization.

b. Contract Studies

Studies have continued on conditions determining the proficiency of complex task performance. The concept of "storage load" (the number of previously occurring events the subject must be remembering at any given response occasion) has been experimentally tested and appears to generalize broadly to numerous conditions involving short term retention.

Experiments have been conducted to discover the interfering effect of irrelevant information and the specific conditions under which extraneous stimuli are most deleterious to performance. It has been demonstrated experimentally that differential frequency of a stimulus as well as the physical characteristics of the stimulus pattern influence the identification of ambiguous visual stimuli.

A study has been initiated on the psychological influences of gastro-intestinal activity. The effects of several "stressful" conditions upon the activity of the gastro-intestinal tract under normal and "tranquillized" conditions will be observed by means of recording from external electrodes.

Another study recently initiated on the retention of tracking skills will utilize the specially constructed "BETA" computer to observe the phenomenon of "reminiscence" in motor learning.

Task VI - Studies in Somesthetic Functions

a. U. S. ARMY MEDICAL RESEARCH LABORATORY

A series of vibration studies on rate is drawing to completion. With displacement at 0.25 inches, a frequency of 15 cps brought no changes. Lethality increased regularly with increase in frequency, 40 cps killing in less than one minute. Young rats (three months) are more resistant than old rats (six months). Generally, females and castrated males of three months of age are more resistant than intact males. Primary and lethal pathology was myocardial and pulmonary hemorrhage. Less severe vibration produced general metabolic reduction with lowered food intake, reduced weight and activity. Behavioral studies indicate that despite the lowered activity there is little or no reduction in learning ability as such. Within ten days after cessation of vibration, weight, food intake and activity returned to normal levels. A present study is concerned with learning more about avoidance and escape behavior of rats with reference to severe vibration in order to be able to make comparisons with other noxious stimuli about which more is known.

Work on primates, on mid-brain action, on skin sensitivity, and on whole body vibration has been conducted, with primary interest in the effects on behavior. These studies generally indicated that gross physiological changes occur before behavioral decrement takes place.

A series of studies of skin sensitivity was recently begun. Presently, work is proceeding on variations of skin sensitivity as related to body locus, to include the assessment of absolute identification levels and tolerance limits for varied electrical current intensities. This work is related to the development of a communication system utilizing the skin as a receiver.

b. Contract Studies

The study concerning the effects of low frequency, high amplitude whole body vertical vibration has continued. Eighteen human subjects were exposed to vibrations (while seated on a wooden chair in a mechanical shake table) of 2.5 and 3.5 cps at displacement amplitudes of .125", .250", and .562", for 90 minute periods. Their performance was compared to a no-vibration condition on hand tremor, visual acuity, compensatory tracking, foot pressure constancy, body equilibrium, and foot reaction time. Performance decrements were found for visual acuity, compensatory tracking, and foot pressure constancy.

The study dealing with the neural correlates of thermal sensation has continued. Skin temperature has been shown to be an important variable in the sensitivity to warmth and cool, especially in the latter. A rather marked change in the absolute threshold takes place in the cool threshold at skin temperatures, between 33°C and 35°C. Temperature thresholds of the cornea, a tissue without vascularity, have been determined, but it was suggested that the cornea per se is not warm or cool sensitive, but that subcorneal structures, (e.g. the iris) mediate this sensation.

The basic design of the study on subjective intensity functions in somesthesis has been completed. Apparatus construction is proceeding. Data will be collected to establish subjective scales of magnitude for the estimation of cold, warmth and pressure and to determine the interaction among these sensitivities.

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APPENDIX IV

U. S. ARMY ORDNANCE CORPS CURRENT WORK PROGRAMS AND BIBLIOGRAPHIES IN HUMAN FACTORS ENGINEERING

A. CURRENT WORK PROGRAM

U. S. Army Ordnance Human Engineering Laboratories, Aberdeen Proving Ground, Md.

1. Supporting Research Activities

Project	Experimenters	Date Started	Estimated Completion
a. Physiological and Psychological Effects of Muzzle and Breech Blast	J. J. Romba D. F. Carmody Paul Martin	Aug 55	Continuing

This program was initiated to determine the effects of blast parameters on various types of performance. Because of the obvious hazards involved, the program was initiated on an animal level.

Recently 4 adult Rhesus monkeys received 90 shots of 5-7 p.s.i. blast pressure produced by a 106mm recoilless rifle. Two weeks of psychological testing was resumed beginning 1 June - eight weeks after the last blast treatment session. Some of the findings were: (1) Some psychological functions were impaired without apparent physical alterations; (2) Trembling was noted in two animals at varied times outside the experimental treatment situation; (3) A decrement in performance resulted in some animals on standard psychological tests such as delayed response and object discrimination; and (4) No changes were observed on locomotive activity and the motor coordination test. These behavioral changes, however, could not be attributed, with any assurance, to the 5-7 p.s.i. blast pressure. A follow-up experiment will be undertaken and is now in the planning phase. Several animals are being trained to participate in the study.

Project	Experimenters	Date Started	Estimated Completion
b. Evaluation of High Intensity Impulse Noise on Hearing in Animals	J. J. Romba D. F. Carmody Paul Martin	Mar 59	Mar 60

The purpose of this study is to investigate the effects of high intensity impulse noise on hearing in animals. Initial planning of the research program has been undertaken. The plan encompasses the following: (1) Development of audiometric techniques for Rhesus monkeys; (2) Determination of comparability of monkey and human audiograms; (3) Investigation of decrement in hearing to lower intensity impulse noise as measured by audiograms on both monkeys and humans; and (4) Study of decrement of hearing in animals but not humans above safe thresholds.

Project	Experimenters	Date Started	Estimated Completion
c. Evaluation of 105mm and 155mm with and without Muzzle Brakes	H. H. Holland	June 59	June 60

The purpose of the tests being conducted is to determine the peak blast pressures which occur in crew positions around the 105mm and 155mm Howitzer for various gun elevations with and without muzzle brakes attached. These tests will determine the potentially dangerous pressure areas from new models of the subject weapons. These new model weapons will be equipped with muzzle brakes which it is felt may create pressures which will be potentially injurious.

Project	Experimenters	Date Started	Estimated Completion
d. Vigilance and Monitoring	I. Woods	June 59	Continuing

In many of the more complex weapon systems one of the prime functions of an operator is to serve as a monitor of automatic equipment such as a status panel or a radar scope. This

monitoring requirement can be of relatively short duration as in monitoring a status panel prior to firing a weapon or can be of relatively long duration, as required in the monitoring of a radar scope. It is essential to study psychological vigilance and those factors which affect it under normal and stress situations.

The objectives of this task are to provide additional information relating psychological vigilance to physiological indices such as g.s.r. To investigate the effects of social interaction on vigilance or monitoring; and finally to identify display elements which will increase vigilance or monitoring under normal prolonged conditions and also short term stress conditions.

e.	Individual Capabilities and Limitations of Men Operating in Tracked Vehicles for Prolonged Periods of Time	S. A. Hicks	1 Jun 59	1 Jun 60

The objectives of this task are to identify the decrements which may occur to personnel due to prolonged confinement in a personnel carrier and to specify those design considerations which may overcome any adverse effects which may be found.

f.	Power Ratings for Personnel Performing a Cranking Task	S. A. Hicks	1 Jun 59	1 Jun 60

Even though military equipment is highly mechanized it is still often necessary to design equipment which uses the human as a source of power. The job of the engineer designing equipment to be powered by man would be facilitated if he had a curve describing the power which man is capable of for specified periods of time.

The objective of this task is first to determine the power function of a man turning a 7-inch crank against a load of 70 inch-pounds for time periods ranging from 1 to 15 minutes.

g.	An Evaluation of Spotting Rounds and Spotting Techniques for Use in Fire Direction	R. M. Ekstrom	1 Jun 59	1 Jun 60

The use of spotting rounds offers a relatively lightweight inexpensive technique for directing the fire of a major caliber weapon. Because of the short reaction time of modern weapons, both ours and a potential enemy, it is imperative that a major round hit be obtained in the shortest period of time. This time requirement demands that the spotting round and technique be optimized.

The objective of this task is to evaluate the relative efficiency of spotter, tracer, and tracer-spotter rounds for fire direction in light of errors of estimating range and azimuth corrections and indirectly the number of rounds required to get on target.

h.	Visual Detection of High Speed Low Flying Targets	W. F. Wokoun	June 59	Dec 59

This study is designed to determine the probability of detecting high speed low flying aircraft for unaided vision and in the absence of early warning information. Detection probabilities will be obtained for groups of 1, 2, 3, and 4 subjects searching 45, 90, 180 and 360°.

i.	Radar Displays (contract)	J. I. Randall I. A. Woods J. A. Stephens	June 59	June 60

This work has been established in order to develop display techniques to provide the operator with integrated target and local battery information within a defined tactical air space. This work is oriented toward reducing the uncertainties associated with evaluation and decision making processes within the radar complex.

j.	Radar Display Research to Counter Counter-measures	C. Fried	June 59	June 60

This work is oriented toward enhancing the effectiveness of radar displays against an enemy employing electronic counter-measures.

2. Systems Evaluation Activities

The details of the various systems listed below are classified from CONFIDENTIAL to SECRET. These projects represent a continuing effort to provide developing agencies with the necessary specific human factors information to insure operational efficiency of the fully developed systems.

This type of activity demands that project personnel become thoroughly familiar with the military characteristics and the tactical situations envisioned for the system. Following this, detailed consultations are held with design personnel to insure proper cognizance of human factors requirements in the design of the system. In many cases supporting research is conducted to solve human factors engineering problems. An evaluation of component items is performed as soon as the items are available in order to discover any deficiencies. Each of these programs will culminate in an evaluation of the complete operational system under field conditions. Some of the main factors taken into consideration are:

a. Reduction of error-likely situations encountered in the assembly of the unit, handling of component items, checkout procedures, and possible user abuse of equipment.

b. The efficiency with which trained operators can set up and use the equipment.

c. Ease of maintenance.

d. Environmental factors which might affect the efficiency of the system.

e. Deriving detailed standard operating procedures for the system.

The following weapon systems are included in this program:

VIGILANTE	C. N. McCain, Jr.	Continuing
LACROSSE	B. L. Sova, Jr. R. G. Lazar	Continuing
PERSHING	J. R. Erickson	Continuing
DOPLOC	J. P. Torre	Continuing
JUPITER	G. Chaikin	Continuing
SERGEANT	M. Schneider	Continuing
RED EYE	F. W. Wokoun G. L. Horley	Continuing
Infantry Assault Weapon, Light	H. T. Curran, Jr.	Continuing
DAVY CROCKETT	H. D'Angelo, Jr.	Continuing
M113	R. Donley W. J. Doherty	Continuing
XM-60	K. D. Foster	Continuing
SHILLELAGH	F. M. McIntyre	Continuing
MBT	C. G. Moler	Continuing

B. BIBLIOGRAPHY OF PUBLICATIONS SINCE PREVIOUS ANNUAL CONFERENCE

TM 9-58 (U) Indicating (Read-Out) Tube: Human Engineering Application for Informational Displays. Charles S. Cruse.

TM 10-58 (U) An Analysis of the Infantry Assault Weapon, Light (LAW) TV-1 Prototype Rocket Noise. Ray Donle, H. T. Curran, and B. J. King

TM 1-59 (C) A Human Engineering Evaluation of the Dart Missile System - The Range Finder. James P. Toree, Jr., Marvin Schneider, E. C. Weiss.

TM 2-59 (U) A guide to Color Banding for Indicators. W. F. Wokoun and Gerald Chaikin.

TM 3-59 (U) Investigation of Natural Movements in Azimuth and Elevation Lever Control Adjustments for Horizontal and Vertical Positions. R. G. Lazar and J. R. Williams.

TM 4-59 (U) A Human Engineering Evaluation of Spotting Rounds with Respect to Fire Direction Capabilities. Lois F. Ivey and Charles Fried.

TM 5-59 (C) A Human Engineering Evaluation of the SERGEANT Transport and Loading Equipment and Procedures. Marvin Schneider, C. Gordon Moler, David E. Holzen, Kermit D. Foster.

TM 6-59 (U) A Human Engineering Evaluation of the Light Anti-tank Weapon System (LAW) A comparative Evaluation of Sighting Devices. Harold T. Curran and Robert T. Gschwind.

TM 7-59 (U) Relationships of Intermittent Noise, Inter-Signal Interval, and Skin Conductance to Vigilance Behavior. Joseph F. Dardano and Irving Mower.

TM 8-59 (U) The Motivational Effects of Rest Periods on Performance. Samuel A. Hicks.

TM 9-59 (U) A study of the Effects of Continuous Wave Jamming on the Detection of Antiaircraft Operations Center Symbols. Charles Fried. Technical Assistance of Claude D. Patton and Raymond F. Blackmer.

TM 10-59 (U) An Evaluation of Mode Selector Switch Arrangement. Gurdon B. Wattles, Edward C. Weiss and David E. Holzen.

U. S. Army Ordnance Missile Command (AOMC) Redstone Arsenal, Alabama

A. CURRENT WORK PROGRAM

1. ARMY BALLISTIC MISSILE AGENCY (ABMA):

a. Internal

(1) JUPITER - support in the field of human engineering for analysis, design and evaluation of the missile CSE system.

(2) PERSHING - analysis, design, and evaluation from a human engineering point of view of the missile, its ground support equipment and pertaining field operations.

(3) HEL is also doing work on the PERSHING and JUPITER.

b. External

(1) REDSTONE - study on reduced training time for field computer (Psychological Research Associates, Inc.)

(2) REDSTONE - field analysis of the trainer (PRA, Inc.)

(3) PERSHING - task and skill analysis for the missile system (Martin Co.)

2. THE ARMY ROCKET AND GUIDED MISSILE AGENCY (ARGMA):

a. External - This Agency has current and continuing human factors studies involved with the following guided missile projects.

(1) LACROSSE (The Martin Co., HEL)

(2) SERGEANT (JPL - HEL)

(3) HAWK (Raytheon Corp, Dunlap & Assoc., HEL)

(4) NIKE HERCULES (BTL, DAC)

(5) REDEYE (Convair - HEL)

(6) AAOC Radar Symbol Studies (HEL)

(7) LAW (Hesse-Epstern, HEL)

(8) NIKE ZEUS (BTL, DAC)

B. BIBLIOGRAPHY

(All external work done for AOMC is published by HEL/APG or the contractor)

Ordnance Tank-Automotive Command, Detroit Arsenal, Center Line, Michigan

Current studies include:

Ride studies
Noise and vibration studies
Shock and loading limitation studies

Ordnance Weapons Command, Rock Island, Illinois

Coordination of the human engineering activities as pertains to mission items is a primary activity of this Headquarters. Analysis and application of sound human engineering practices is carried on by personnel at each of the development Arsenals of the Command.

A continuing program of reviewing projects and technical reports concerning development items and a constant search of new literature is being carried on in order to assist all design personnel on human factors problems.

Rock Island Arsenal, Rock Island, Illinois

Current human factors engineering: human engineering evaluation of LITTLE JOHN and HONEST JOHN rocket launcher systems.

Picatinny Arsenal, Dover, New Jersey

A. CURRENT WORK PROGRAM

1. Basic Project Work

Human factors specialists are working members of the "design team" for the warhead section phases of the following nuclear projects:

a. PERSHING
b. LITTLE JOHN
c. NIKE ZEUS
d. HONEST JOHN
e. JUPITER
f. SERGEANT

The participation in team design efforts extends also to the DAVY CROCKETT Project, NIBLICK, XM51 Rocket Motor Production Engineering, and other classified items.

Human factors areas considered include:

a. Analysis of tasks
b. Personnel requirements
c. Training requirements
d. Manuals and check sheets
e. Test equipment

f. Handling equipment
g. Packing and Shipping
h. Assembly
i. Work space layout
j. Maintenance
k. Pre-and-In-Flight activities
l. System synthesis

The methods used are both analytical and empirical, and the results consist of detailed design recommendations for the consideration of, and the implementation by, the project manager.

2. Supporting Research

a. Control/Display Ratio. Investigations are being conducted to arrive at optimal C/D ratios, torque, and control sizes for setting information into devices. A systematic examination of the following variables is involved:

(1) Operator strength
(2) Position of controls relative to operator
(3) Control dimensions
(4) Output characteristics
(5) Environmental effects

b. Rangefinding. This study is concerned with an exhaustive examination of available research data concerning rangefinding and range estimation procedures, devices and methods. The resulting annotated bibliography and derived implications are expected to be applied to a long term program of studies which will investigate the overall area of human factors in rangefinding.

c. Latch, Catch and Fasteners. This study was initiated in an effort to classify, evaluate, and recommend application parameters for various categories of fastening hardware.

3. Special Studies

Empirical investigations are performed which are aimed at evaluating specific pieces of equipment or devices. Currently underway is an evaluation of the probability of detection of the anti-vehicular T1200E2 Fuze and Tilt Rod.

4. Systems Analysis

Although studies of this sort may include an experimental phase, they are primarily analytical in nature. Currently, a study is being conducted of the effectiveness of new departures in anti-personnel items in terms their patterns and density of dispersion; optimal external, physical characteristics; and of methods and devices for distributing the items.

5. Miscellaneous Activities

Consultation. Almost 1/2-man/year per year is devoted to consulting with design personnel on matters of optimal design of equipment; incidental matters involving psychological, biological, or anthropological data; or in disseminating information relative to human factors. In addition, a quarterly human factors bulletin is distributed which discusses recent topics of widespread interest and which informs R&D personnel of available human factors engineering resources.

B. BIBLIOGRAPHY OF PUBLISHED REPORTS SINCE LAST CONFERENCE

Engineering Research Laboratory Technical Memoranda

a. In Press An evaluation of the Human Factors design of JUPITER Test equipment.

b. In Press Evaluation of the Probability of Detection of the T1200E2 Fuze and Tilt Rod.

c. In Press Human Factors Analysis of Target Location Errors.

d. In Press Human Factors in Rangefinding and Range Estimation.

Springfield Armory, Springfield, Massachusetts

Human Factors Projects currently being sponsored by Springfield Armory are as follows:

a. Weapon Weight Distribution Program: Phase I which covers the study of the weapon weight distribution of several past and present military weapons as compared to a selected control weapon of known superior handling characteristics is nearing completion. It is expected that useable design data in the form of graphs and mathematical formulae will soon be available. This program will be continued through additional study phases to determine the effect of weapon weight distribution on the efficiency of the man-weapon combination.

b. Sight Configuration Study: Several sight systems of various configurations have been fabricated and now await modification of the facilities at Test Branch to provide a range with controllable illumination levels. It is planned to test these and other promising designs to determine weapon sight effectiveness at various illumination levels.

c. Weapon Stock Study: A special try-stock has been designed which permits varying the orientation of the integral stock areas by which the man controls the weapon during firing (i.e., butt plate, cheek pad and pistol grip). It is planned to fabricate one such try-stock and continue this study to determine the optimum configuration for shoulder weapon stocks.

Watertown Arsenal, Watertown, Massachusetts

Current human factors engineering activities are being conducted in the design of the XM33 Launcher and VIGILANTE "A".

U. S. Army Ordnance Arsenal, Watervliet, Watervliet, New York

Project	Experimenter	Date Started	Estimated Completion
1. VIGILANTE	G. R. DeTogni	Jan 57	Jun 60

A study of the armament tipping parts package was initiated to investigate man-machine performance and safety in stressful environments. Reaction time was determined to analyze the need for fire warning safety devices. Proof tests were witnessed to secure actual loading time and review various operational and maintenance tasks.

2. Pivot or Separable Chamber Gun	G. R. DeTogni	Apr 56	Sept 59

This armament is being studied with emphasis on Arctic operation and manual loading using completely combustible cartridge case ammunition. Areas of investigation are being established to permit evaluation of firing tests.

3. Environmental Studies	G. R. DeTogni	Oct 55	Continuing

Environmental test requirements for the 1959-60 test season were submitted for the 81mm Mortar, T227E2; 4.2" Mortar T201; 155mm Howitzer T255; 90mm Recoilless Rifle T219; 40mm Flash Suppressor (Dwg. No. D8766088); and 8" Howitzer, M47.

4. Environmental Studies	G. R. DeTogni	Nov 58	Dec 58

The T106 (M34) Firing Lock for bag-loaded cannon was evaluated while operated with the bulkiest Arctic handwear. Handle size, configuration, location, thermal insulating properties and physical forces required during slow, rapid and sustained fire were considered.

5. Environmental Studies	G. R. DeTogni	Jun 59	Continuing

Data regarding protective clothing were forwarded to designers who are planning a series of cold room tests on obturation system components for bag loaded cannon.

6. SHILLELAGH	G. R. DeTogni	Jul 59	Jul 60

Human factor requirements were defined for the armament portions of this system at a meeting of potential contractors. Provisions of OPI 7-381, Human Factors Engineering Contract Clause, were discussed with emphasis on the operational and maintenance aspects of weapon usage.

7. Cannon Muzzle Blast	G. R. DeTogni	Aug 58	Oct 59

Requirements were established outlining the variables involved in the calculation of blast pressure from artillery cannon during early design stages. A proposal submitted to the National Inventors Council is being evaluated to determine the merit of using peak sound pressures to determine peak blast amplitudes in the cannon crew's work area.

8. 105mm Gun T254E2	G. R. DeTogni	Jun 59	Dec 59

Action has been initiated to coordinate the evaluation of the T254E2 Gun - M60 Tank system with HEL at APG.

Frankford Arsenal, Philadelphia, Pennsylvania

A. CURRENT WORK PROGRAM

Project	Experimenters	Date Started	Estimated Completion
1. DAVY CROCKETT	W. Gaymon A. Charles Karr	Sept 58	Jun 60

This project involves the human engineering evaluation of two weapon systems. Due to the security aspects of the project, the evaluation of the systems can only be discussed in general terms.

One of the system studies progressed to a satisfactory completion at the Human Factors Section and was consequently turned over to APG for a further phase of testing.

The evaluation of the second system is still in progress. The work to date has been a consideration of four potential problem areas: (1) Location of controls; (2) Man portability; (3) Operation of system, including speed and accuracy in normal and extreme environmental conditions; (4) Maintenance and safety, including such considerations as minimum number of tools necessary to effect "in field" maintenance, ease of maintenance, ruggedness of system under conditions of climatic extremes and prolonged usage.

2. Design of Instrumentation for Evaluating Human Operating Equipment	PFC H. Brawley L. Gallun	Apr 59	Continuing

This project is concerned with designing and constructing electronic equipment which will be used to evaluate systems and components in terms of reaction times.

The basic assumption is that in the optimum operation of complex systems simple and disjunctive reaction times may legitimately be used as dependent variables; hence, these reaction times can be used as criteria for evaluating the relative difficulty of different systems.

Presently, the equipment provides for visual presentation of stimuli (limited now to three colored lights). Provision is made for three different subject responses: pressing a hand button, depressing a foot pedal, speaking into a microphone. Errors are indicated by a buzzer. Responses that constitute errors and are signaled as such are: anticipation, incorrect choice of response, and simultaneous multiple responses. The equipment is set up to handle large numbers of stimulus-response combinations and more of these will be investigated in the future.

3. Shoulder-Fired Recoilless Rifles	J. Tulencik E. McGuigan	Sept 57	Continuing

Human Engineering Problems connected with Shoulder-Fired Recoilless Rifles. The purpose of this continuing project is to investigate the usual human engineering problems in the design of weapon systems as well as unique problems related to shoulder-fired recoilless rifles in particular. Several different weapon systems are involved, including MAW, SQAT, and PAT.

Some of the problems under investigation are:

1. Design and location of components: e.g., determining the optimal vertical and horizontal distance between the shoulder rest and sight. If one location cannot accommodate 95% of user personnel, a range of sight adjustments needed will be determined.

2. Feasibility of using sub-caliber spotters in order to increase first-round hit probability.

3. Problems in steadiness and aiming errors. Methods of reducing aiming errors are being investigated which include empirical tests of reticle designs, trigger and pistol grip designs, and aids in steadying the weapon.

4. Problems in tracking moving targets from four firing positions: sitting, kneeling, standing, and prone.

4. HAW	L. Gallun	May 59	May 61

The proposed experimentation on this project will be an attempt to obtain data to determine the proper pistol grip and firing mechanism to use on this weapon system. Some of the parameters to be investigated are the location of the pistol grip, type of firing mechanism to use for both the spotter and main rounds, the determination of the optimum angle of the pistol grip with respect to the barrel.

Mock-ups are in the process of being designed so that, with the aid of microswitches, data may be obtained on the best type of triggering devices to be used, with special consideration to the design of an effective safety switch which will prevent the firing of main rounds during the spotting procedure and unintentional firing during tracking, since the pistol grip will be used in combination with the joy stick in tracking on target with the system. It is hoped that the best possible arrangement can be determined as well for the optimum location of joy stick and pistol grip on either side of the barrel. These data will be obtained through simulated firing and tracking studies.

5. EVE	J. Tulencik A. Charles Karr	Jun 58	Jun 60

The EVE system offers the possibility of night-time tank operations through the use of electro-visual equipment. Although related to daytime closed circuit television, the problems involved are such as to require definition of the differences and specific statement of human factors requirements.

At the present time the major human engineering work on this project is being conducted by a consultant to the prime contractor. Prior to letting the contract some ground work was completed by this installation. This included performance of an experiment to determine the effective ranges for surveillance and gun laying accuracy through television. A necessary part of this experiment was the determination of optimal fields of view, consequently magnifications, for surveillance and gun laying accuracy.

Other work in progress at Frankford Arsenal is concerned with problems of depth perception through television, driving with the aid of television, and studies of other applications of television.

6. Tank-Tracking Study	A. Charles Karr	Nov 57	Jun 60

The purpose of this project is to determine the optimal joy-stick control characteristics for anti-tank weapons. To accomplish this goal, a tracking system is being developed which will simulate as closely as possible true tank-tracking problems. As presently conceived, the tracking system will permit the testing of various weapons systems and will be valuable as a training simulator.

7. Human Engineering Consultation STAFF

Human engineering consultation service is provided for all design engineers at Frankford Arsenal. This work frequently entails literature searches to obtain specific design information, and assistance in designing consoles, computers, and other fire control equipment. In the latter case the work begins with concepts and initial drawings, proceeds through construction of wooden mock-ups and performance of experiments with these mock-ups in a systems context, and consultation continues to the end of user tests.

B. BIBLIOGRAPHY OF PUBLISHED REPORTS SINCE LAST CONFERENCE

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PFC Joseph Tulencik
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Report No. M59-24-1 — Human Engineering Evaluation of XM28 (SECRET)
A. Charles Karr
May 1959

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William E. Gaymon
September 1959

Human Factors Section Intra-Arsenal Reports

Report No. FA-A-51 — Analysis of Proposed EVE Test Program
PFC John Barron
August 1958

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Warren H. Teichner
September 1958

Report No. FA-A-53 — Preliminary Human Engineering Evaluation of XM29
A. Charles Karr
March 1959

Report No. FA-A-54 — Human Engineering Report on Spotter Firing Test of T219 Recoilless Rifle
July 1959

APPENDIX V

U. S. ARMY QUARTERMASTER CORPS
CURRENT WORK PROGRAMS AND BIBLIOGRAPHIES IN HUMAN FACTORS ENGINEERING

Quartermaster Research and Engineering Center, Natick, Massachusetts

A. CURRENT WORK PROGRAM

Critical Environmental Factors and the QM-Equipped Soldier

Studies	Experimenter	Date Started	Date Completed
1. Effects of cold stress and other stress variables on detection of multiple-channel stimuli.	R. A. Gardner	July 59	June 60

The purpose of this study is to determine the effect of cold and other stressful conditions in altering the relationships among stimulus patterns adequate to be detected by the soldier under prolonged periods of observation.

2. Effects of loud noise on sensory perception.	A. Cohen	July 59	June 60

There is some evidence to indicate disruption of perceptual processes due to exposure to loud noise. This study is intended to determine the critical noise thresholds below which soldiers can correctly make perceptual judgments and maintain acceptable levels of performance. The findings should be applicable to headgear design parameters.

3. Effects of prolonged small group isolation upon sensory and performance processes.	B. J. Fine	July 59	June 60

Military situations frequently require small combat groups to maintain high levels of tactical efficiency in isolated situations. The present study is intended to determine the effects of isolation and climatic extremes on small groups. The data obtained should provide guidance information for the design, improvement and techniques for use of equipment.

4. Study of individual differences in pain thresholds and pain tolerance.	E. R. Dusek	July 59	June 60

The purpose of this study is to obtain data concerning threshold values for stressful pain stimuli. These data will be related to soldier responses to other conditions producing other types of environmental stress.

5. Effects of hand cooling and amount of task training on manual performance.	B. J. Fine	Mar 59	June 60

The purpose of these studies is to determine the relationships which may exist between the amount of training in a manual task and the decrement in manual performance which may be expected to occur under conditions of cold exposure. These studies are expected to provide fundamental guidance information for the improvement of handwear items.

6. Psychological and performance characteristics under multiple stress conditions.	B. J. Fine	July 59	June 60

This study is intended to isolate individual characteristics of soldiers which will predict success or failure under various stressful conditions experienced in a military environment.

Studies of Soldier-Equipment-Environment Systems and Incompatibilities

1. Development of techniques to identify and study incompatibilities.	J. M. McGinnis	Mar 59	June 60

This effort is intended to develop standardized techniques for identifying and analyzing incompatibilities among man-machine systems in the operational situation. Such techniques will provide a convenient and systematic method for pin-pointing specific incompatibilities, and provide an increasing fund of comparison information for quicker analysis of incompatibilities in the future.

2. Studies of incompatibilities between the QM-equipped soldier and Ordnance missiles and weapons.	J. M. McGinnis	June 59	June 60

These studies are aimed at preventing incompatibilities between Ordnance missiles and weapons systems and related items of QM equipment. Emphasis is on providing relevant information to the designers during design and development phases of work on a new item or system.

3. Operation and maintenance problems associated with use of the rough-terrain fork-lift truck.	R. L. Mendenhall	Jan 59	June 60

These studies are intended to provide guidance information for improvements in design of the rough-terrain fork-lift truck to allow improved efficiency of operation and easier maintenance procedures.

4. Assessment of armor requirements for protection of aircraft crewmen.	T. H. Burkhalter	Jan 59	June 60

This is a field study to obtain and collate information pertaining to the hazards against which Army aviators require armor protection. The information obtained will be used in guiding the designers of body armor.

Human Engineering for Design and Development of QM Items

1. Investigation of handwear variables and insulation to provide improved manual performance and protection.	A. Cohen	Jan 59	June 60

The study is intended to provide guidance to designers concerning optimum amounts of and placement of insulation to allow adequate thermal protection and minimum interference with manual performance.

2. Development of systems for evaluating manual performance.	J. L. Kobrick	July 59	June 60

A need exists for a systematic method of performing routine laboratory evaluations of prototype handwear items during the design stage, as well as obtaining guidance information for prediction of optimum designs of handwear for specific uses. Such a test battery would provide these services.

3. Isolation of basic manual movements and effects of cold exposure on same.	J. L. Kobrick	July 59	June 60

This study is intended to provide a detailed breakdown of the elements of manual movement. This will provide a means of analyzing future operational situations in which specialized handwear is required.

4. Effects of extreme climatic conditions on hearing thresholds.	A. Cohen	July 59	June 60

This study is intended to determine the degree to which hearing is affected by climatic extremes in order to advise equipment designers of the need for acoustic and thermal insulation to be incorporated in prototype headgear items.

5. Effects of steady state and impulse-type noise on hearing.	A. Cohen	July 59	June 60

The purpose of this study is to determine the degree to which insulation is needed to attentuate steady state and impulse-type noise. The study will provide guidance information to engineers and designers concerned with headgear development.

6. Usefulness of facial protection to reduce environmental effects on visual functions.	B. Crist	July 59	June 60

This study is intended to indicate the degree of importance of providing protection to the face in reducing the effects of wind and low temperature on visual functions.

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Quartermaster Food and Container Institute, Chicago, Illinois (Food Acceptance Branch)

A. CURRENT WORK PROGRAM

Study	Investigator	Started	Completed
I. Methods for measuring and predicting food acceptance.			
Interactions of taste qualities.	J.M. Kamen	Oct 1957	May 1960

A systematic investigation of how each of the primary taste qualities affects each other will provide basic information on the mechanisms of taste perception.

Study of a new method of interviewing.	R.W. Seaton	Jan 1959	Jan 1960

The content, quantity and other aspects of opinion, attitude and acceptance data have been shown to depend in part on the manner and means with which the data are collected. The present investigation is concerned with effects on food-attitude data of presenting stimulus material (questions) by means of a respondent-controlled dictating machine.

Food preferences of men in the Armed Forces.	D.R. Peryam F.J. Pilgrim	Jan 1949	Dec 1959

A series of eight surveys of food preference attitudes have been conducted on more than 400 foods. The data have been analyzed for differences among foods and food classes and for effects of demographic factors on preference. A monograph is being prepared.

Variability in the taste perceptions of different compounds.	D.R. Peryam	Jan 1959	Mar 1960

Some substances serve as ambiguous stimuli. Responses vary with people as well as with concentration. The degree of variation in the description of the taste component of flavors is being studied to improve flavor analysis techniques.

Study of thresholds and quality judgments of odorants in relation to their physico-chemical properties.	F.J. Pilgrim (Contract)	May 1958	Jun 1960

Descriptive attributes of odors have been classified by factor analysis. The relationship of these factors to such measures as infrared and ultra-violet absorption, surface tension and vapor pressure are being investigated to develop basic knowledge of olfaction and improve methods for flavor analysis.

Study of interaction of preference qualities of food samples served successively.	J.M. Kamen	Sep 1957	Jun 1960

It has been established that in taste tests, samples of food may affect the ratings of different and subsequent samples of the same foods. The investigation of causes of these effects will increase the interpretability of taste test ratings.

Behavioral indices of acceptance.	J.M. Kamen	Jun 1958	Jun 1960

Establishment of less ambiguous criteria of acceptable rations and ration components requires the study of various aspects of consumption behavior. Field studies of consumption, and the causes of non-consumption, will provide a sounder basis for more clearly defining acceptable foods.

In-flight reactions to components of semi-solid meals.	F.J. Pilgrim	Aug 1959	Mar 1960

Components of semi-solid meals designed for use under high-altitude conditions have been studied for acceptability under laboratory and flight-simulation conditions. Their acceptability under actual prolonged flight conditions will be examined next.

Study of personal and attitudinal factors associated with resistance to irradiated foods.	R.W. Seaton	Jan 1959	Jan 1960

Contemporary ambivalent feelings about peaceful and other uses of irradiation may crystalize negatively with regard to irradiated food if latent resistance factors become socially normative. Identification of population subgroups, personality types, and attitudes conducive to establishment of such negative norms is being conducted.

II. Optimizing feeding systems under restrictions imposed by tactics, logistics, nutrition, climate and cost.

Exploration of unusual field conditions to identify factors in the environment and operations that may alter food attitudes and acceptability.	D.R. Peryam	Mar 1959	Mar 1960

Preference and utility of several operational rations are being studied during use by small groups under Arctic conditions. Personality factors are also being studied.

Compatibility of menu items.	F.J. Pilgrim	Jul 1958	Feb 1960

Pilot studies showed that the suitability of menu combinations, such as meat and potatoes could not be predicted adequately from preferences for the individual items. A rating procedure was developed for studying combinations and a large scale survey was conducted at four Army posts. Data are being analyzed. A report will be prepared to guide menu planners.

Repetitive menu cycles in the feeding of small groups.	J.M. Kamen	Nov 1958	Mar 1960

Foods served at a too great frequency often produce adverse behavioral effects. Among the aspects of this problem that will be experimentally studied are: different menu cycle lengths, canned vs. dehydrated, variation of menu combinations.

Study of the bases for changing food attitudes.	R.W. Seaton (contract)	Mar 1958	Jun 1960

New or unusual foods engineered to meet special logistical requirements of mobile war may encounter widespread rejection if introduced into the military ration system without accompanying operations aimed at offsetting possible fears and prejudices against such foods. Ways of changing such possible resistances are being studied.

Relations of feeding procedures to social-psychological attributes of small groups.	R.W. Seaton	Jun 1958	Jun 1960

Non-nutritional uses of foods may include increasing de.'rable inter-personal interaction attributes of small groups preparing and eating their food under isolated or field conditions. Possible effects of different feeding arrangements are being examined.

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APPENDIX VI

U. S. ARMY SIGNAL CORPS
CURRENT WORK PROGRAMS AND BIBLIOGRAPHY IN HUMAN FACTORS ENGINEERING

A. CURRENT WORK PROGRAM

1. In Service. The Human Factors Engineering Program within USASRDL continues the training, product review, consultation and contract surveillance activities, all of which have been described in past conference reports. The results are becoming evident in new equipments which appear to be well designed from the human factors standpoint.

2. Contracts.

Contract No.	Contractor	Duration
DA-36-039 so-73253	Dunlap and Associates, Inc.	1 Aug 57 - 1 Sep 59

Studies underway on this task assignment type contract are:

Human Engineering Design of Remote Control System AN/UPW-1
Study of the Speed and Accuracy Penalties of Multi-Scales Meters
Pattern Recognition Errors Associated with I.R. Display
Human Factors in Detonation Location Central AN/GSS-5
Human Engineering Study of Environmental Conditions in Signal Corps Shelters and Vans
Human Engineering Review of Radio Set AN/GRC-53
Human Engineering Review of Telephones TA-312/PT with Special Reference to Design of Ease of Hangup.

DA-36-039 sc-78328	Applied Psychology Corporation	1 Jun 59 - 31 May 60

Design Standards for Man-Machine Tasks in Signal Corps Systems

In general the systems engineer plans the gross function of the man in the system and the design engineer determines the man-machine interactions. To assist these engineers development of a set of task-descriptive terms applicable to the many possible human functions and interactions has been initiated. Terms such as radar operation, computer programming, receiver alignment, oscilloscope readout, and pattern recognition are too gross for explicitly defining human tasks in relation to the machine. Primary effort in this research will be toward developing task classification categories and a code of descriptive terms for these categories so that human functions involving perceptual, cognitive, and motor capabilities may be logically designed into the system at both planning and design stages. Major emphasis will be placed upon complex display and display-control functions of nonroutine nature. Where possible, terms that are meaningfully descriptive of both human and machine functioning will be employed.

B. COMPLETED PROJECTS

1. In Service: Signal Corps Technical Requirement SCL-1787A, 13 April 1959. This supersedes SCL-1787, 3 April 1958, which it condenses. The new specification, in conjunction with a new standard paragraph for inclusion in research and development specifications, outlines and sets up requirements for early and continued inclusion of appropriate human factors engineering effort at the beginning of, and throughout the development cycle.

2. Contracts.

Contract No.	Contractor	Completion Date
DA-36-039 sc-75054	American Institute for Research	July 31, 1959

Human Engineering Design Recommendations for Miniaturized Equipment.

Completion of this project helps to provide some answers to the growing problem of controlling, maintaining, and displaying information when using drastically miniaturized equipment. Of immediate value is the "Guide to Human Engineering of Miniaturized Equipment," which provides in condensed form much useful analytical and applied information for use in the design of small equipments. In addition to much useful quantitative data, the guide presents some concepts and solutions for dealing with miniaturized design. The concept of the swept arc and volume, and the multi-sided rotatable instrument panel are examples of important contributions to this burgeoning design problem.

DA-36-039 sc-66488 American Institute for Research 30 June 1959

Development of an Index of Electronic Maintainability

This was performed under contract to U. S. Army Signal Equipment Support Agency, Fort Monmouth, Maintenance Engineering Department. Robert E. Redform was the cognizant project supervisor. This study develops a technique for measuring the maintainability of electronic equipment during its development cycle, and through a maintainability index, provides a method for determining whether the maintainability of an equipment meets the requirements of the user. The study offers a research report, an evaluation booklet, and an instruction manual for applying the index. The problem is outlined, maintainability standards are presented, the rationale of the index is discussed, and a procedure for applying the index is specified. Maintainability scoring is based upon five "Maintenance consequence areas," down time, maintenance time, logistics, damage, and injury, and upon nine design factors, including display and controls, external accessibility, and test points. This effort is considered a first step in the maintainability area, in the evolution of a technology for the design of man-machine systems.

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